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Interim Forest Tree Improvement Guides for the Central States


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G. A. Limstrom

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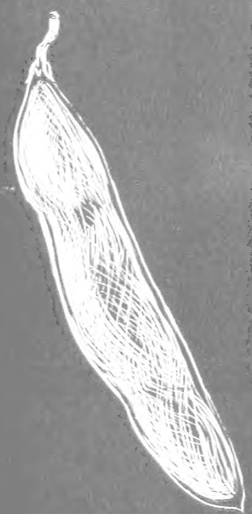
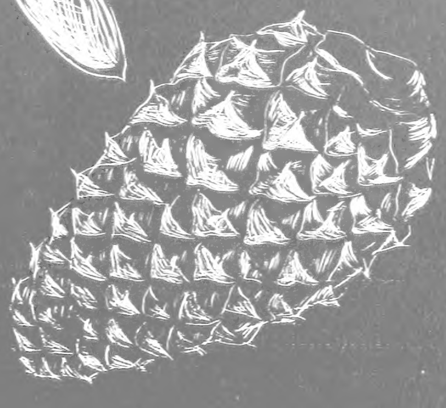
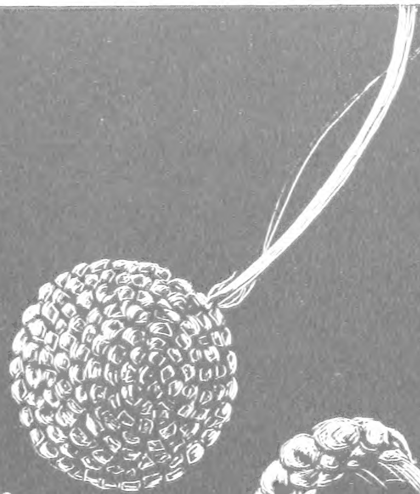

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Foreword

The Central States Forest Tree Improvement Committee was organized in 1958 to foster tree improvement programs in the Central States. This region, which once produced some of the finest hardwoods on the continent, can regain its prominence in this field only by concentrated research and action programs, including tree improvement.

The Committee is made up of any and all who are interested in forest genetics. The objectives of the Committee's tree improvement program coincide so closely with those of the Station in this field that we are glad to be able to participate generally in its activities and especially glad to contribute personnel and editorial services and facilities for this joint publication.

High on the Committee's list of objectives has been the development of guides for the selection of superior seed trees, best sources of seed for planting, and the establishment of seed-production areas and seed orchards. This publication, "Interim Forest Tree Improvement Guides for the Central States," is the first of a series of papers the Committee plans to prepare to meet this objective.

R. D. LANE, Director
Central States Forest Experiment Station

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Interim Forest Tree Improvement Guides for the Central States

G. A. Limstrom

Several million acres are in need of tree planting in the six central states of Illinois, Indiana, Iowa, Kentucky, Missouri, and Ohio. More than 50,000 acres are planted annually and many different tree species are used. To increase forest-planting success in the region we must look closely at all possible influences on quality and yield of plantations. One of the most important influences — yet often overlooked — is the origin and quality of seed. Not until recently has the great importance of proper seed and its effect on the potential value of plantations been realized (figs. 1 and 2). In the past many of our seed-procurement policies have been "penny wise and pound foolish." Seed has been purchased at the lowest price without regard to how its origin influences the value of plantations. Some efforts to avoid these errors have been made during the past few years even when the result has sometimes been higher costs for seed. Efforts include insistence on "certified" or "verified" seed, more careful selection of seed trees from which to make collections, and establishment of seed-production areas and seed orchards.

Assembled here are information available on seed procurement and guides for getting better seed for tree planting in the Central States region. The guides are interim recommendations to be followed until more research and experience reveal better practices for each species. New findings should be utilized as soon as available. For some species we have good leads; for other species information is scanty. This publication reports the latest research findings and the considered judgment of foresters experienced in tree improvement.

FIGURE 1 (Left).—A poorly formed black walnut growing in the open may produce abundant seed for cheap collection, but unless trial plantings are available, we do not know what kind of timber can be grown from seed of this tree.

FIGURE 2 (Right).—Seed from this walnut of excellent form and growth will likely yield a higher percentage of trees with favorable form and growth rate than seed from tree shown in figure 1.

Selection of Seed Sources

Geographical Variations

Geographical origin of seed sometimes makes the difference between success or failure of a tree plantation. Origin profoundly influences survival, growth, and quality of trees. It also influences resistance to disease, insects, drought, frost, and "snow-bend." Tree hardiness in the face of adverse temperature, wind, and drought is also influenced by geographical origin. Thus planting success will depend greatly on how suitable a new environment is for a species' rather fixed growth pattern.

As a result of many generations of natural selection, tree species have become genetically adapted to a definite environment (6).[1] Individuals of some species tolerate a wider range of environmental conditions than individuals of other species (*3*); the range to which some species are adapted is very restricted. Environmental conditions that may limit the area of planting in the Central States will be considered one by one. These include temperature, precipitation, latitude, and humidity. Geographical zones established for seed collection in the Central States will then be described. These zones can be used to help assure that different races of a species will be planted under conditions to which they are adapted. But first it would be helpful to review the climate and topography of the general area.

Local climate in the Central States is greatly influenced by latitude, winds, and storms with their associated air masses (*100*). Because of its mid-continental location, the region as a whole is cold in winter, hot in summer. Prevailing winds are southwesterly in summer, northwesterly in winter. The tempering effects of Lake Michigan and Lake Erie extend inland for only a few miles. Due mainly to differences in latitude, temperatures not only differ strikingly between summer and winter but also from north to south in the region, even in the same season.

[1]Numbers in parentheses refer to Literature Cited, page 51.

Altitude and topography also influence regional and local climate. The Ozark highlands in Missouri, for example, are generally cooler than the adjacent areas. But hilly areas — including the Ozarks — that are so characteristic of much of the Central States present special problems. Frosts occur later in the spring and earlier in the fall in the lowlands than in the uplands of hilly areas regardless of general elevation of the areas.

Average annual rainfall and temperature are lower in the northern than in the southern part of the region. The average summer humidity is lower and evaporation rates higher in the western than in the eastern part of the region. Rains are also less frequent throughout the year in the western than in the eastern part.

Temperature

The general effects of temperature on plant survival and growth are well known (*77*). Aspects of temperature that have the most significant effects in the Central States insofar as choice of seed sources for tree planting is concerned are minimum temperature, killing spring frosts (*63*), length of the frost-free growing season, and average growing-season temperature.

Low temperature is so critical for plants that hardiness zone maps (*146*) have been based

on the average minimum winter temperature alone. These maps show the limits for planting species and are used for horticultural and landscaping purposes. Shortleaf pine (*Pinus echinata* Mill.) grows well in southern Illinois, but survives only precariously in northern Illinois. Tolerance to minimum temperatures often differs as much between different geographical sources of the same species as between different species. Loblolly pine (*P. taeda* L.) from Maryland, for example, tolerates much lower winter temperatures than loblolly pine from Georgia (*162*).

Frost hardiness differs with season (*71*): it increases gradually from midsummer to fall, increases sharply in late fall when succulent branches have "hardened off," and reaches a peak in midwinter. Then resistance to freezing temperature decreases gradually towards spring and drops sharply after the new, succulent growth begins.

Frosts in early fall or late spring may be more damaging, however, than low midwinter temperature. In the Central States some species and seed sources are especially susceptible to late killing frosts. Such frosts occur most frequently in lowlands or on lower slopes of steeply dissected terrain. In Ohio, for example, yellow-poplar (*Liriodendron tulipifera* L.) from a Mississippi source was twice as susceptible to late spring frost injury as yellow-poplar from a Michigan source (*41*). Sometimes effects are the opposite. In Ohio, Kriebel (*72*) reported more spring frost injury to sugar maple (*Acer saccharum* Marsh.) from sources north of this State than to that from sources to the south. In this species the northern sources break dormancy earlier in the spring than southern sources. The southern sources, on the other hand, continue growth longer in the fall and sustain most frost injury then. Local sources, intermediate in the time that they break dormancy in spring and harden off in fall, sustain the least overall damage from frost.

Although the significant effect of soil and air temperature on plant growth is recognized, the optimum range for good development of species used for tree planting in the Central States has not been determined. Work in Africa has shown that not all fruit-tree species do best in the same range of mean summer temperature (*71*). There is, however, doubt that mean summer temperature is a reliable criterion for judging species suitability to a certain climate. Although we have little specific information on this, Kriebel (*72*) has noted that high temperature injures leaves of sugar maple from the Appalachian, northeastern, and Canadian sources planted in Ohio more severely than it damages those of sources from south and west of Ohio.

Thermoperiodism is the relation between day and night temperatures. It may be more important, at least for some species, than mean temperature. Kramer, for example, found that growth of loblolly pine seedlings was related more closely to the difference between day and night temperatures than it was to a given range in temperature (*70*). The influence of temperature on transpiration rates is also no doubt highly significant.

Precipitation

Geographical variations attributed to differences in precipitation appear to be related chiefly to amount, distribution, and manner of fall. Drought resistance, as reported for green ash (*Fraxinus pennsylvanica* Marsh.) by Meuli and Shirley (*91*), in sugar maple by Kriebel (*72*), and in loblolly pine by Zobel (*177*), appears to be greater in sources from the drier than the wetter part of the species range. Although we do not yet have experimental evidence, it seems likely that sources for such species as eastern redcedar (*Juniperus virginiana* L.) and black walnut (*Juglans nigra* L.) from the western edge of the Central States would be more drought resistant than sources from the eastern border of the region.

Loblolly pines from northern seed sources were damaged much less in Illinois as a result of "snow-bend" and "snow-breakage" than trees from southern seed sources.

Latitude

Some factors associated with latitude that affect geographical variation, such as minimum temperature and length of growing season (*85*), have already been described. Others, such as day length during the growing season, are equally important (*149, 150*). In general, trees planted far south of seed origin grow much slower than the trees of native seed origin. Trees planted far north of seed origin often grow faster than trees of local seed origin, but may be susceptible to injury from extreme temperatures. This general response, for reasons not yet fully understood, applies to species that complete terminal growth before the longest day (in June) as well as to species that continue growth until fall. In a white pine (*P. strobus* L.) seed-source study in Ohio and Illinois, for example, young trees from seed sources in Georgia, North Carolina, and Tennessee grew 1½ to 2 times as fast as trees from local sources. Dormancy in trees of these sources breaks later in the spring than the local source. Because of this and because seasonal growth has ended by midsummer, severe frost damage to growing tips is unlikely.

Native white ash (*F. americana* L.) in Connecticut may begin shoot growth around May 1 and complete most of the season's growth by June 15 (*70*). On the other hand, native white ash in North Carolina may begin shoot growth a month earlier, that is about April 1, and complete most of the season's growth by May 1. And though the dates this growth takes place vary, the length of the growing period and pattern of growth will not change even when trees are planted in locations far from their place of origin.

Evaporation and Humidity

The availability of soil moisture for plant survival in the Central States is affected by east-west climatic differences. This is perhaps the most significant influence on species distribution in the region. Losses of water by evaporation and transpiration tend to offset gains in available soil moisture resulting from precipitation or ground water. Losses fluctuate mainly as the result of changes in relative humidity, winds, and temperature. The outcome is that the western part of the region is drier in summer than central and eastern parts. Potential evaporation losses in the western part of the region for the summer season alone are often equal to or greater than the total annual precipitation. Drought resistance, then, is a primary requisite for trees to survive and is no doubt important in limiting the present natural range of many species in the region. Studies in Oklahoma by Rice (*114*) illustrate the importance of these climatic factors in limiting the distribution of trees. His studies of sugar maple in Devils Canyon in western Oklahoma (about 185 miles west of the more-or-less continuous range of this species in eastern Oklahoma) show a striking similarity in the microclimate in the stands in both areas.

Seed-Collection Zones foı the Central States

Seed-collection zones have been established in the U. S. Forest Service's Lake States region (120, 122), in California (39), and in other regions and states. The main purpose of setting up zones has been to encourage the use of local seed and to discourage the use of seed that may not be suitable or may be of inferior quality for planting in the zone. In the regions where zones have already been established, only a few species (sometimes just one) have been involved. In the Central States, however, where many species are used for planting, the problem of setting up seed-collection zones is more complex. Zones are urgently needed.

We cannot fix definite seed-collection-zone boundaries that could be used for all species. Seed from any part of the natural range of some species may be suitable for planting in a particular locality, while seed from only a small part of the natural range of other species may be suitable. Seed from some sources of a species may be less adapted to a particular locality than seed from other sources. The seed may be particularly susceptible to drought there, while seed from certain sources of another species may not be adapted because of susceptibility

to late spring frost. For both species one or more sources may be found adapted to the locality.

The seed-collection zones set up for the Central States (fig. 3) are based on the climatic (*141*) and geographic conditions considered most critical in limiting the distribution and planting range of trees commonly used in our planting program (table 1). Zones are, with two exceptions, those used on the "Plant Hardiness Zone Map" of the United States and Canada, prepared by the U.S. Agricultural Research Service (*146*). One exception is that the small area fringing Lakes Erie and Michigan, designated as a special subzone on the map, has been combined with the subzone surrounding it. Also, because of critical frost conditions in the Ozarks (*26*), a special subzone (6c) has been established for that locality. Subzones can be divided by indicating states to create designations such as 5b-Mo, 5b-Ill, etc., and even further divided if necessary for precipitation distribution sectors by indicating direction such as 6a-Oh-E, 5b-Mo-W, etc. Although based primarily on minimum temperature isotherms, zone boundaries also reflect differences in annual precipitation, temperature, frost occurrence in spring and fall, number of frost-free days, and latitude (table 2). Each subzone is characterized by one or more distinctive feature (*25*).

By use of the zone, subzone, and even more restrictive designations, we can prescribe small geographical units for collection of seed, if this is desired for some species. On the other hand, for other species with no important racial variation over extensive areas, we can prescribe large areas such as the whole of zone 6.

Climatic zones can also be used in selecting a source when procurement of seed from out of the state and region is necessary. Seed

TABLE 1.—Conditions influencing boundaries of seed-collection zones in the Central States

Possible limiting factors	General direction of change	Critical attributes
Precipitation		
Average annual	South (most) to north (least)	Drought
Distribution	East (most uniform) to west	Drought
Temperature		
Average in July	South (highest) to north (lowest)	Heat, drought
Average annual minimum	North (lowest) to south (highest)	Freezing, dessication
Killing frosts, spring	North (latest) to south (earliest)	Injury to new growth
Growing season	South (longest) to north (shortest)	Annual growth
Evaporation	West (highest) to east (lowest)	Drought
Relative humidity	East (highest) to west (lowest)	Drought
Photoperiod	South (shortest in summer) to north (longest)	Growth (dates and duration)
Topography	Lowland (later spring frosts) to upland (later fall frosts)	Injury to current growth

Zone number	Mean temperatures		Distribution of precipitation[2]		
	Minimum annual[1] (^{o} F.)	July mean (^{o}F.)	80-100 days	100-120 days	120+ days
			Average annual precipitation (inches)		
4	-20 to -30	72	29		
5	-10 to -20	74	36	36	38
6	0 to -10	77	43	42	41
7	5 to 0	80		49	49

[1]Approximate range of average annual minimum temperatures.
[2]Average number of days in year with 0.01 inch or more.

Seed Collection Zone boundaries

Seed Collection Subzone boundaries

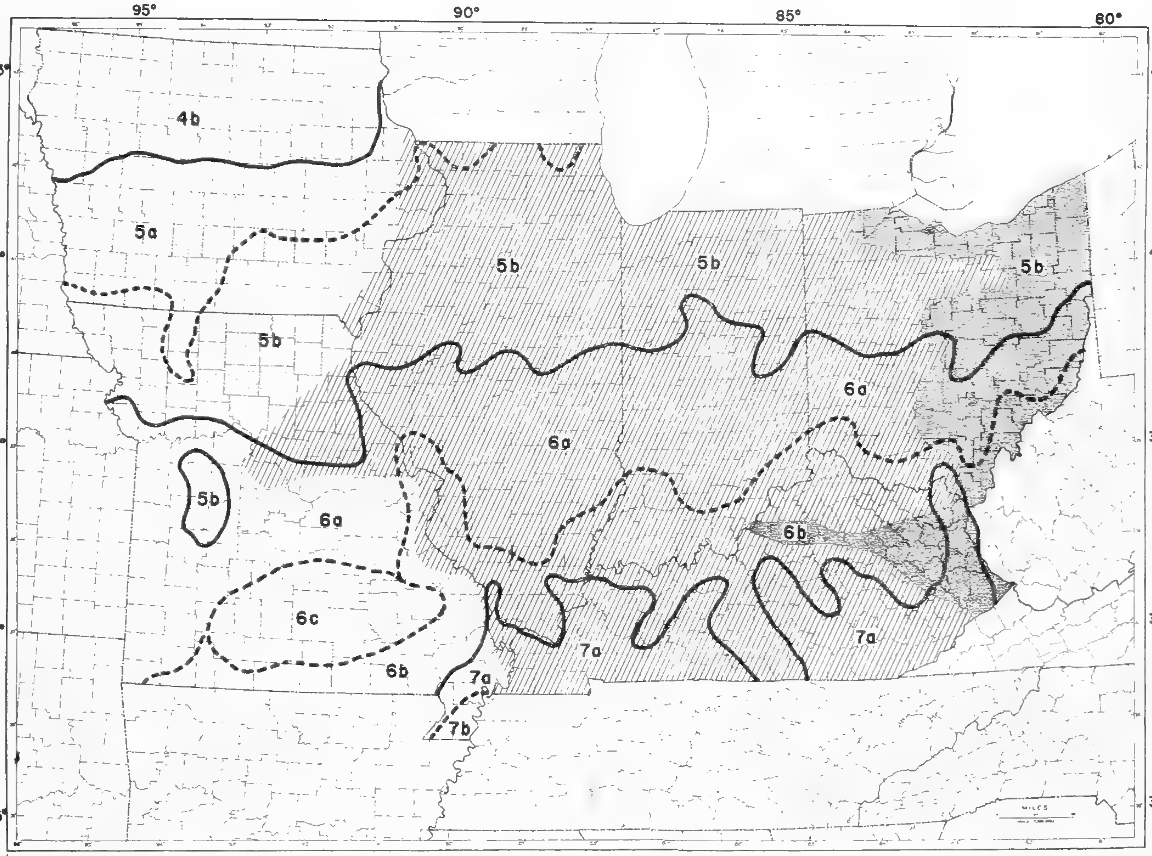


FIGURE 3.—Seed-collection zones for the Central States.

from collection zones similar in climate to the regions in which planting is planned should be considered the most desirable — unless seed from unlike collection zones has been found to be more satisfactory. Differences in latitude, minimum temperature, and length of growing season should be carefully checked. Some may be critical for one species and unimportant for others. Yellow-poplar and sweetgum (*Liquidambar styraciflua* L.), if exposed to long day length, will break dormancy early and then be more susceptible to late spring frosts (*71*). Both species will continue growth later in the fall than many other species, and are therefore susceptible to early killing frosts. White pine, on the other hand, stops growth in midsummer or earlier (*130*).

These seed-collection zones for the Central States, based largely on climatic and geographic conditions and supplemented by some provenance research, are intended to serve only until more precise limits can be determined by experimentation. A southwide seed-source study (*154*), for example, was designed to prescribe seed-collection zones for the important southern pines.

TABLE 2.—Significant features of seed-collection zones in the Central States

State and zone	Latitude	Total cumulative daylight[1]	Precipitation: Average annual[2]	Precipitation: Dist.[3] (days/yr.)	Temperature: July average	Temperature: Minimum[4]	Temperature: Frost[5]	Temperature: Frost-free days	Evaporation[6]	Relative humidity[7]
	Degrees north	Hours	Inches	Number	Degrees F.	Degrees F.	Date	Number	Inches	Percent
Iowa										
4	42–44	312	29	80–100	72	–25	May 10	145	33	50
5	40–43	292	33	80–100	74	–15	Apr. 30	160	35	45
Missouri										
5	39–41	282	36	80–100	77	–15	Apr. 25	175	35	47
6ab	36–40	261	43	80–100	78	– 5	Apr. 20	190	36	51
6c	37–38	251	43	80–100	76	– 5	May 5	175	37	52
7	35–37	246	47	80–100	80	5	Apr. 5	210	35	53
Illinois										
5	40–43	292	34	100–120	74	–15	Apr. 30	165	30	53
6	37–40	271	42	100–120	77	– 5	Apr. 25	185	33	50.
Indiana										
5	40–42	292	36	100–120	74	–15	May 10	160	28	53
6	38–40	271	42	100–120	77	– 5	Apr. 30	180	32	50
Ohio										
5	40–42	292	35	100–140	73	–15	May 10	160	27	53
6	38–40	266	40	100–140	75	– 5	Apr. 30	170	28	53
Kentucky										
6	36–39	261	44	100–120	77	– 5	Apr. 20	185	32	55
7	36–39	251	49	100–140	78	5	Apr. 20	190	30	55

1/ Total cumulative daylight in excess of 12 hours per day from sunrise to sunset, March 21 to September 22.
2/ (147).
3/ Average number of days in year with 0.01 inch or more precipitation (147).
4/ Average annual minimum temperature (146).
5/ Average date of last killing frost in spring (147).
6/ Normal April to October evaporation from reservoirs and shallow lakes (151).
7/ Average relative humidity, local at noon, July (147).

Individual Tree Variations

Equally as important as geographical origin of seed — and sometimes even more so — is the proper selection of individual seed trees within a geographic seed source (*169*). We have mounting evidence that the quality of a seed tree is a good index to the quality of many of its offspring (*59*). For example, the chances are good that seedlings of forked or crooked seed trees will also be forked or crooked. More progeny studies are needed, however, to determine the extent and character of traits that are inherited.

There are many traits to look for in selecting trees for seed collection (*13, 60*). Some traits can be identified by examining a tree carefully and comparing it with adjacent trees of the same species; other traits can be identified only from increment cores or other wood samples (*37*) that must be analyzed in the laboratory.

Traits Visible in Standing Trees

Visible traits that may be evaluated in standing trees may influence both yield and quality of progenies. Some of these traits are readily discernible (*21*); others can be judged only from close observation (*38*). A few of the criteria used apply to the lower 17 feet of the tree, assuming that most of the selections will be trees with at least one merchantable 16-foot log. If smaller trees are considered as seed trees, the specifications should apply to the height of the tree of smallest merchantable diameter. Take the example where 4 inches diameter outside bark is the minimum size for pulpwood. For a tree 4 inches in diameter at a height of 12 feet, this height is set as the upper limit for counting number of branches and surface defects or in assessing the straightness of the stem.

Stem form

Stem form includes such traits as apical dominance, straightness, roundness, taper, forking, and lean.

Apical dominance. — This is the tendency of trees to maintain a single, dominant stem throughout the crown. Minimum acceptable standards will vary with each species. In general, conifers should maintain a straight, single stem for more than 90 percent of their total height. For some hardwoods, such as sycamore (*Platanus occidentalis* L.), sweetgum, black walnut, and several oaks (*Quercus* spp.), trees with as little as 70 percent of total height in a single straight stem are acceptable.

Straightness. — This is one of the easiest traits to evaluate but nevertheless one of the most essential. Excessive sweep or crook greatly reduces log scale and wood quality. For practical purposes a tree trunk may have a little sweep or crook and yet classify as "straight." With practice, an examiner may become very proficient in judging whether a tree is straight enough to be acceptable. But some quantitative measure is desirable for keeping records and for making comparisons. The following standards are suggested:

Very straight if edge of stem from stump (or upper end of butt-swell) to 17-foot height is a straight line.

Straight if edge of stem departs less than 2 inches from a straight line at any point.

Crooked if edge of stem departs 2 to 4 inches from a straight line at any point.

Very crooked if edge of stem departs more than 4 inches from a straight line at any point.

Taper. — To classify taper the use of the Girard form class is suggested. This is the ratio of the diameter inside bark at a 17-foot height to the diameter outside bark at breast height. Form class may vary greatly with species, site, tree age, and stand density. For this reason its use should be restricted to comparison of trees in the same stand.

Roundness. — Roundness is especially desirable in veneer bolts to be rotary-cut and moderately desirable in sawtimber and pulp-

wood (fig. 4). Roundness has a significant effect on wood quality because elliptical logs are likely to have much undesirable tension and compression wood. The easiest way to determine roundness is to measure the largest and smallest d.b.h. of the tree with calipers. If the smallest d.b.h. is 0.95 times the largest d.b.h. or more, the tree is classed as "round"; if only 0.85 to 0.95 the tree is classed as "oval"; and if less than 0.85 the tree is classed as "very oval" or "elliptical."

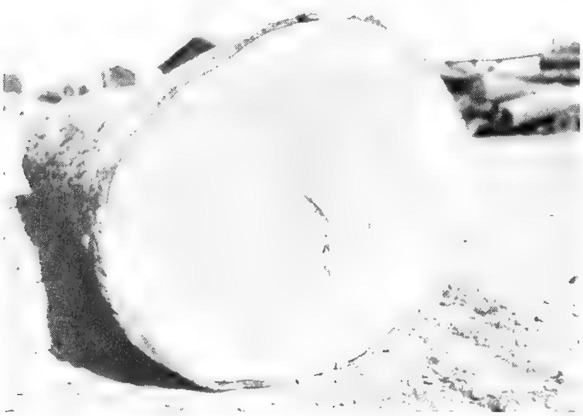


FIGURE 4.—Roundness is one of many traits to consider in selecting desirable seed trees. This elliptical shape is particularly objectionable in a veneer log and moderately undesirable even in a saw log.

Lean. — Lean significantly affects wood quality (*64*); its heritability is somewhat obscure (*133*). To be sure, trees with excessive lean should not be selected as seed trees. For all species except the oaks, a tree with a 1-degree lean or less (almost vertical) is "highly satisfactory," one with 1- to 3-degree lean is "satisfactory," and one with more than 3-degree lean is "unsatisfactory." Oaks appear to lean more than any other species used for planting in the region, perhaps because they commonly regenerate by sprouting. Trees with less than a 1-degree lean would be hard to find. We suggest that oaks leaning less than 2 degrees be classed as "highly satisfactory" and those leaning 2 to 4 degrees be classed as "satisfactory." Lean can be easily measured by using a plumb bob and line attached to the zero point on a transparent semicircular protractor (Appendix, page 57).

Number of branches

Kind and extent of branching are traits to consider in selecting seed trees. This includes number, size, and tendency toward epicormic branching. The number of branches in the first 16-foot log is an indicator of natural pruning.

There is some evidence that epicormic branching and forking are influenced to some extent by heredity (*34*) (figs. 5, 6, and 7). In dense stands the tendency toward epicormic branching may be difficult to discern. In establishing seed-production areas, stands are usually thinned in two or more operations. As this thinning opens up the stands, trees with a tendency toward epicormic branching become more evident. These trees can therefore be "rogued out" in subsequent thinnings.

A tree may be straight and round and a fast grower, but have more branches on its lower stem than other trees in the stand. Such a tree should not automatically be disqualified as a prospective seed tree. If progeny of such trees in commercial stands of the future are otherwise superior, it would seem that some limbiness could be tolerated, as the adverse effects of this trait can be reduced by pruning. The number of lower branches is affected by age and density of the stand as well as by heredity. For rating this characteristic then, the following classification is suggested:

Number of branches below 17 feet (fully stocked stand)	*Rating*
None	Very high
1 to 4	High
4 to 8	Fair
More than 8	Low

For moderately stocked and understocked stands and for some species with branch whorls, more branches in each grade could be tolerated.

FIGURE 5.—White oak with much epicormic branching, an undesirable trait.

FIGURE 6.—Forking in white oak, an undesirable trait that may be inherited (28).

FIGURE 7.—White oak with several highly desirable traits—straight, good self-pruning, no epicormic branching, dominant, and fast-growing.

Size and angle of branches

Both of these traits affect the amount of knot defects in lumber. Trees with small branches are preferred. Generally, branches that extend outward at about a 90-degree (right) angle from the tree are preferred over those that sweep upward or droop (figs. 8, 9, and 10).

Because of extreme differences between species and sites, it seems impractical to rigidly differentiate between "small" and "large" branches. When seed trees of a specific species are being selected in a given locality a classification of branch size based on general observation of species and sites should be prepared before rating of trees begins. Acceptable standards of branch angle will differ with species and products. For purposes of classification, however, angle of branching from the main stem in the middle of the crown is rated about as follows:

Branch angle	*Rating*
Horizontal (75° to 90°)	High
Nearly horizontal (45° to 75°)	Satisfactory
Acute (less than 45° angle)	Poor

Branch angles can be easily measured with reasonable accuracy by use of a plumb bob and line attached to the zero point of a transparent semicircular protractor (Appendix, page 57).

Growth rate

When the possibilities of tree improvement became evident in this country less than two decades ago, the first or primary objective was to find fast-growing trees. This remains an objective today. But other traits are commanding much attention, often to the point where rapid growth is second, third, or even lower priority in selecting seed trees. For some species the fastest growing trees may lack resistance to pests, drought, extreme temperatures or may not provide the highest quality product. The objectives of planting, and particularly the quality of the products desired, must therefore be considered in choosing between fast-, moderate-, or slow-growing trees (*102, 103, 104*). For most species and products, however, fast-growing trees are still desired.

Height and diameter are the best criteria for comparing growth rates. But diameter growth is influenced more by environment (especially stand density) than is tree height. For this reason, it is better to use the relative heights of trees at some age than to use relative diameters in comparing growth. It is easier to make selections in immature, even-aged stands than in mature, uneven-aged stands. Selection is also easier in pure than in mixed stands. In even-aged stands particularly, it is best to rate growth on the basis of tree crown position. Dominants should rate "high," codominants "acceptable," and intermediates "low." Trees more than 10 percent taller than the average dominant should rate "very high" in growth rate.

Surface defects

In addition to branches, branch stubs, and sprouts from epicormic branching which already have been discussed, surface defects include bumps, bulges, burls, and swells (*80*). They also include visible defects caused by disease or insects (figs. 11 and 12). For seed-tree selection, surface defects do not include degrade due to fire scars or interior defects not detectable on the surface of the tree. We do not know just how much different defects are influenced by heredity. To minimize errors, however, the number of these defects in the tree should be carefully considered before selecting it as a seed tree. For example, a recent study of central hardwoods by Boyce and Schroeder (*11*) showed that trees with less than four surface defects had a probability of more than 80 percent of producing Grade 1 butt logs. In comparison, trees with more than eight surface defects had a probability of producing such logs of less than 20 percent. Their analysis of more than 1,100 log diagrams of upland oaks and yellow-poplar showed only 6 percent

FIGURE 10.— Yellow - poplar: small branches and good self-pruning. Tree in center has good branch angle (right angles), while more acute branch angle of tree at right is less desirable.

FIGURE 8.— Undesirable branching characteristics in yellow-poplar; note thickness and acute angle of branches of all these trees.

FIGURE 9.—Yellow-poplar: angle of branching is satisfactory but branches are long and heavy; self-pruning is poor.

FIGURE 11.—Surface defects in butt log of white oak: bumps and branch stubs.

FIGURE 12.—Surface defect in butt log of white oak: swells or bulges indicative of interior defects.

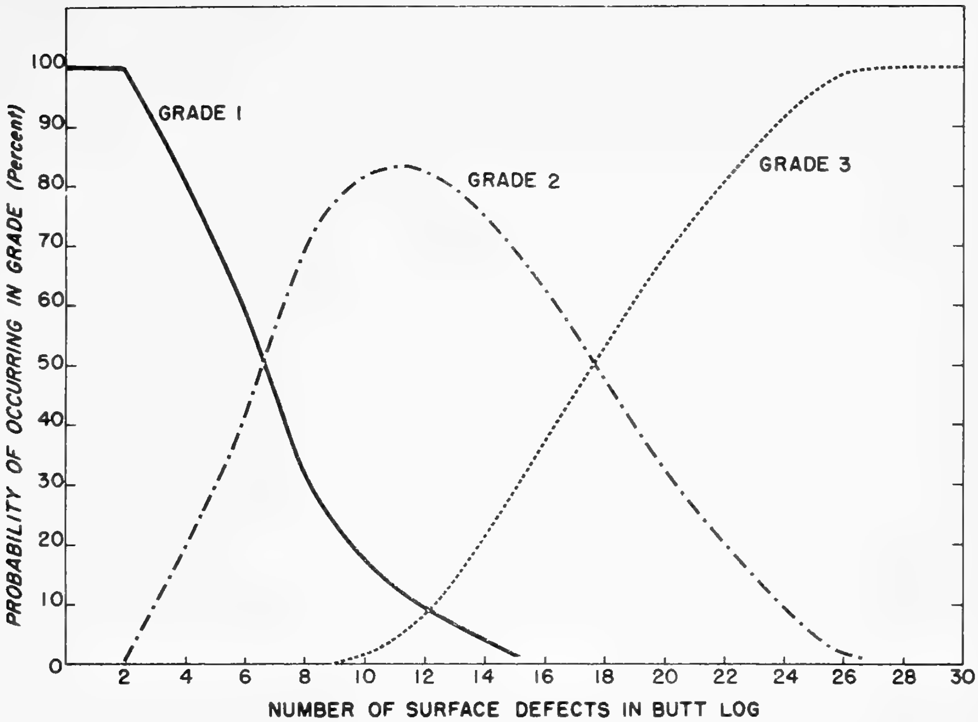
of trees had four or less surface defects in the butt log. But 81 percent of these logs were Grade 1 (fig. 13). From these studies we can set up criteria for ranking prospective seed trees for this trait as follows:

Number of surface defects in first 17 feet	*Ranking*
4 or less	Very high
5 to 8	High
8 to 12	Acceptable
More than 12	Low — unacceptable

Other visible traits

A few other visible traits should also be considered in seed-tree selection. These include susceptibility to climatic or biological injury. Trees severely damaged by insects or disease should be rejected as potential seed trees (*55, 61*). Those seriously malformed because of glaze, snow-bend, sunscald, or wind-breakage should also be rejected. On the other hand, trees that have escaped injury in stands seriously damaged by these things may be good trees to preserve as sources of seed and scion material.

FIGURE 13.—Probable grade distribution of butt logs by number of defects (11).



Seed production. — There is a tendency to rate seed production too highly in selecting seed trees. To be sure, it is a necessary consideration, but many trees possessing the most desirable wood properties are poor seed producers. Poor seed crops, no doubt influenced by heredity to some extent, may be due to poor crown development and in some years to deficient soil moisture. Trees producing little seed because of poor crown development may produce heavier crops after they have been given more room to grow by thinning out adjacent trees. The size of the seed crop produced in a given year by a tree in a dense stand should not, therefore, be the basis for rejecting it as a potential seed source. For dioecious species the number of male trees in the vicinity of the seed tree could also affect the size of the seed crop; they should be carefully selected and preserved to assure good pollination.

Grain and twist. — Sometimes careful examination of the outer bark reveals signs of twist (figs. 14 and 15), but it may be necessary to cut a sample of the bark and examine the grain of the inner bark. If definite twist is evident the tree should be rejected as a seed tree. Either straight or curly grain, visible on the inner bark, is a good trait; curly grain is especially desirable for some products such as veneer.

Traits Not Visible in Standing Trees

The traits not visible in standing trees (wood composition, structure, density, etc.) — but essential in selecting seed trees — mainly involve wood quality (*5, 24, 97*) (table 3). They are of utmost importance; in fact, many of the traits visible in standing trees already discussed are considered only because of their influence on wood quality (*64*). Most wood-quality determinations require specially trained personnel and equipment (*65*). For such work forest research centers and agricultural experiment stations should be contacted and arrangements made to submit increment cores and other wood samples (*8, 152*). As current and proposed research proceeds, other traits may also prove to be significant (*66, 76, 96, 98, 99, 101, 110, 111*).

FIGURE 14 (Left).—A white oak tree with irregularities and small breaks in the bark that indicate hidden knots. Ridges and furrows of the bark follow a spiral course and indicate spiral grain in the wood.

FIGURE 15 (Right).—A white oak tree with straight grain indicated by ridges and furrows in the bark that are parallel to the longitudinal axis of the trunk.

TABLE 3.—Relative importance of traits in the selection of trees for seed collection

TRAITS VISIBLE IN STANDING TREE

Trait	Product desired			
	Saw logs	Veneer	Pulp	Poles
	Relative Importance			
Stem form				
Straight, single stem	High	High	High	High
Taper	Medium	Medium	Low	High
Roundness	Medium	High	Low	Medium
Lean	High	High	High	High
Branching habit				
Number	High	High	Medium	Medium
Branch angle	High	High	Low	Medium
Natural pruning	High	High	Low	Medium
Epicormic branching	High	High	Low	Medium
Growth rate				
Rapid height and diameter growth	Differs[1]	Differs[1]	Medium	Medium
Uniform diameter and height growth	High	High	Medium	Medium
Resistance to disease, insects, and climatic factors	High	High	High	High
Surface defects				
Bumps, bulges, burls, swells, conks, etc. in butt log	High	High	Medium	Medium

TRAITS NOT VISIBLE IN STANDING TREE

Trait	Saw logs	Veneer	Pulp	Poles
Chemical composition	Medium	Medium	High	Medium
Density (Specific gravity)	High	Medium	Differs[1]	High
Percent summerwood	High	High	High	High
Fibril angle	High	Medium	High	Medium
Growth rate (ring width)	Differs[1]	High	Medium	Medium
Reaction wood (compression and tension)	High	High	High	Low
Fiber and tracheid size	Medium	Medium	High	Medium
Sapwood thickness	Differs[1]	Differs[1]	High	High
Grain	Medium	High	Low	Low
Interior defects	High	High	High	High

1/ Differs with species and products.

Purchase Specifications

Before seed or planting stock is purchased, it is a good idea to set up minimum standards. These must take into account the acceptability of different geographic sources and individual tree traits (*155*). But other specifications can also be used to help decide whether a particular lot of seed is desirable and the most desirable source in purchasing seed. At the present time there seems to be no standard terminology for classifying seed for forest planting. But a committee of the Society of American Foresters has proposed standards of seed certification. These have been adopted by the International Crop Improvement Association (ICIA) and generally accepted by the forestry profession (*126*). Using these standards for degrees of seed certification, and adding another term for seed that cannot be certified, the following seed specifications are suggested.

Seed grade	Specifications	Preference rating
Certified seed	From genetically superior trees:	
	a. Proven by progeny tests in seed-collection subzones where trees will be planted.	1
	b. Proven by progeny tests outside subzone, but in locality with similar climatic and geographic features.	2
Selected-tree seed	Not progeny-tested; but seed is from rigidly selected trees or stands that have promise but not proof of genetic superiority. From trees in seed-collection subzone or localities with similar climatic and geographic features.	3
Source-identified seed	Not progeny-tested, but seed will be from natural stands and successful plantations of known geographic origin in seed-collection subzone, or from other localities with similar climatic and geographic features.	4
Questionable seed	Neither certified nor selected:	
	a. Geographic location of seed trees only approximately known. No knowledge of seed-tree characteristics.	5
	b. Geographic location and characteristics of seed trees not known.	6

It should be understood that the labels "certified," "selected-trees," or "source-identified" on a seed lot do not necessarily mean that the seed is suitable for any locality or product. If source and tree quality are specified on the label, be certain that both meet specifications you need for each locality and product.

Producing Improved Seed

Seed or planting stock is often purchased. But the planting agency may itself collect seed and produce its own planting stock. In large planting programs, seed or stock is pur-

chased for some species and obtained through supervised collections for others. When seed or stock is purchased, seed source and quality should be specified in the sale agreement or contract. Specifications may be set up by policy statements or directives when the planting organization itself collects seed. But whether purchased or collected directly, seed can be designated as from:

Seed-collection areas. — Trees or stands, planted or natural, that have not been treated or managed for seed production.

Seed-production areas. — Natural trees or stands or ones planted mainly for timber production that have been developed and managed specifically for seed production.

Seed orchards. — Plantations established specifically for seed production, usually from seed trees of acceptable origin and quality, and preferably from progeny-tested seed trees.

Seed from any of the three preceding sources may be progeny tested (preferred) or not progeny tested.

Seed-Collection Areas

Seed-collection areas have not been treated in any way to improve seed production. They may be unmanaged "wild" stands or managed for timber production. Until seed-production areas or seed orchards are available, seed-collection areas will be the principal source of seed for planting. They should be selected carefully, and the best may be developed as seed-production areas or become a source of superior trees from which seed or scion wood could be obtained for seed orchards.

Often the best source of seed for some of our valuable hardwoods is a stand located on privately owned land. It is often permissible for public agencies to collect seed from these areas but difficult or impossible to develop the stand as a seed-production area. This may be important in deciding which species should be given highest priority in developing seed orchards.

Seed-collection areas should be located in stands having a high percentage of trees with desirable traits. The stand should be reported on cards similar to that shown in the Appendix, page 57.

Seed-Production Areas

Species Priorities

More than 40 different species of trees are now planted in the Central States. The number of trees differs by species, of course; but it is obvious that some priority in establishing seed-production areas will be necessary. The following points should be considered:

Present and future need for planting stock by species.

Availability of suitable stands and trees.

Availability of suitable seed. — For example, if seed of suitable quality and origin for a certain species is available from a neighboring state or from another reliable source, perhaps "reciprocal seed treaties" could be arranged. Other species would then be given priority over that one for establishing seed-production areas.

Practicability. — It may be more practical to establish seed-production areas for heavy-seeded species, such as the oaks and walnuts, whose seed can be collected on the ground directly beneath the crowns, than for the lighter seeded species, such as ash and yellow-poplar, whose seed is so scattered by the wind that it must be collected from the tree — a tedious and expensive method.

Relative feasibility of seed-production areas versus seed orchards. — The outlook for oak seed orchards in the near future, for example, is much poorer than for yellow-poplar or walnut seed orchards. Seed-production areas for the oaks, therefore, should rate higher priority than for yellow-poplar and walnut.

Most of the hardwood seedling production for forest planting in public nurseries for the past few years has involved less than 10 species: green and white ash, eastern cottonwood (*Populus deltoides* Bartr.), northern red oak (*Q. rubra* L.), white oak (*Q. alba* L.), sweetgum, sycamore, black walnut, and yellow-poplar. These are the hardwood species that will no doubt receive first attention in plans for seed-production areas and seed orchards.

How Many Seed Trees and Seed-Production Areas?

In order to answer this question a number of factors need to be considered (*84*):

Flowering Habits

Flowers of some species may have both pistils and stamens (perfect). Other species may have separate male and female flowers. These may be borne on the same tree (monoecious) or on different trees (dioecious). Male and female flowers may mature at the same time or at different times. Such aspects of flowering are important because they must be considered before deciding how many seed trees per area are needed (*163*). For example, an excellent tree of a dioecious species may produce abundant pistillate flowers. But it will produce little or no seed if there are no trees with staminate flowers nearby to assure good pollination. And some monoecious species such as black walnut, sycamore, and many conifers are dichogamous. This means that even though male and female flowers are borne on the same tree, they ripen at different times (fig. 16), thus preventing self-pollination. It may then be necessary to have several trees in close proximity to each other to insure pollination. Other species with perfect flowers may produce a small amount of self-pollinated seed, but as in yellow-poplar very little seed is viable. There is also mounting evidence that cross-pollination in yellow-poplar results in not only more viable seed (*7*) but seedlings that are more vigorous. (*17*).

FIGURE 16.—Black walnut flowers. Prominent male flowers appear at end of preceding year's growth and are pendent and catkin-like. Female flowers are visible at the end of twig from which leaves have been removed (current year's growth). Female flowers are not receptive at time pollen of the same tree is ripe (dichogamy), thus reducing the amount of self-pollination.

Pollination and Compatibility

We know that most species first in priority for seed-production areas in the region are cross-pollinated but that some self-pollination occurs in yellow-poplar. Both yellow-poplar and sugar maple are insect pollinated while all of the other species of importance are most likely wind pollinated. We know very little about compatibility; until we do more trees per area should be left to assure fertilization than might be required if this were known (*51, 74, 168*). For example, Boyce and Kaeiser (*10*) found that in yellow-poplar the chance of incompatibility in a natural stand was greater for trees near each other than for trees some distance apart.

We do not as yet have much precise information on the distances pollen is blown by wind (*164*). For all of the species under consideration except eastern cottonwood, however, the effective pollination distance can be considered to be less than 400 feet. A knowledge of this range is important in removing undesirable trees. It is also useful in determining whether there are enough trees close to the seed tree for good cross-pollination.

Frequency of Good Seed Crops

In planning the number of seed trees needed for seed production, the frequency of good crop years must be considered. Some species have good crops nearly every year while others may have crops at longer or irregular intervals. The minimum number of seed trees should depend on whether seed is wanted for use only the year after a good crop or whether seed from a good crop is to be stored and used in equal quantities over several years.

The minimum numbers of seed trees needed to supply seed for planting 100,000 trees has been estimated for species most commonly planted in the Central States (table 4). Figures are based on estimated production during good crop years (*50*). For example, the minimum number of white ash seed trees recommended, 15, is for a good crop year, and good crops are expected to occur every 3 years. If 100,000 white ash seedlings are required every year then a minimum of 45 seed trees should be planned.

TABLE 4.—Flowering and seeding habits to consider in setting up seed-production areas, by species

Species	Flowering habit	Frequency of good crops	Minimum number seed trees for 100,000 trees per year
		Years	
Alder, European	Monoecious	1-2	1/ 1
Ash, green	Dioecious	1	1/ 10
Ash, white	Dioecious	3	15
Cottonwood, eastern	Dioecious	1	2/ 1
Larch, European	Monoecious	5-10	20
Larch, Japanese	Monoecious	?	20
Locust, black 3/	Perfect	1	25
Maple, silver 3/	Polygamo-dioecious	1	5
Maple, sugar 3/	Polygamous 4/	2-5	15
Oak, northern red 5/	Monoecious	3	100
Oak, white 5/	Monoecious	5	200
Pine, Austrian	Monoecious	3-4	30
Pine, eastern white	Monoecious	3-5	25
Pine, jack	Monoecious	3-5	20
Pine, loblolly	Monoecious	3-10	25
Pine, red	Monoecious	3-7	60
Pine, Scotch	Monoecious	2-3	20
Pine, shortleaf	Monoecious	Erratic	20
Redcedar, eastern	Dioecious	2-3	20
Spruce, Norway	Monoecious	4-5	25
Sweetgum	Monoecious	2	20
Sycamore 5/	Monoecious	3	1/ 1
Walnut, black 5/	Monoecious	2	50
Yellow-poplar 3/ 5/	Perfect	2	1/ 5

1/ In order to insure good pollination and high genetic diversity a minimum of 15 seed trees per area is needed. However, if all seed is to be collected from only one area, a minimum of 50 trees is highly desirable.
2/ May be enough for 300,000 trees.
3/ Insect pollinated; other species in table wind pollinated.
4/ Both perfect and unisexual flowers occur on the same tree.
5/ Some pollination by selfing; most pollination by crossing.

Protection and Genetic Diversity

It would be convenient to have all seed trees in a single area — but risky. Two or more areas offer more assurance that seed production will not be endangered by fire, insects, or disease. They also increase chances that there will be desirable genetic diversity in the plantations to be established. If all seed is to be collected from one area, a minimum of 50 seed trees is desirable.

Selection of Areas

Seed-production areas should be selected and established in cooperation with research agencies. Several things should be considered in making the selection:

Location. — Latitude and climate of seed-production areas should approximate those of areas to be planted. Ideally, seed-production areas should be planned for each subzone where extensive planting is planned.

Quality of stand. — The entire stand should contain many trees that are above average in straightness, self-pruning, vigor, and other desirable characteristics (fig. 17).

Size and age of seed trees. — The Woody-Plant Seed Manual (*147*) and silvical literature give the commercial seed-bearing age. If other conditions are favorable, trees beginning their "optimum seed-bearing age" should be preferred. Some trees growing in dense stands, which from a quality standpoint would be good, have live crowns beginning far above the first log. Some such trees may not develop good crowns for seed production even after thinning.

Accessibility and topography. — Terrain and location of the seed-production area should permit easy access by trucks and collection crews.

Protection. — The areas should, of course, be located where good protection from fire, trespass, and other causes of damage is assured.

Land ownership. — For government agencies, areas should be in public ownership. However, where there may be good potential seed-production areas on private land, leases or easements should be obtained before the areas are developed. Good areas may be adjacent to land owned by others and be subjected to contamination by pollen from undesirable trees on this land. Permission to remove these trees should be obtained before selecting the area for seed production.

FIGURE 17.—Yellow-poplar seed-production area, Morgan-Monroe State Forest, Indiana. (Courtesy Indiana Department of Conservation.)

Selection of Seed Trees

Only general guides that will be useful in selecting seed trees can now be given. The most important traits to consider in grading candidates for seed trees in seed-production areas are given for pulpwood, poles and saw-timber, and veneer logs (table 5).

The first step is to select and specify one or two (never more than three) traits that are most important. It is not practical to attempt to select only trees that possess more of the desired traits (*142*). All seed trees selected should meet the highest specifications for these one to three traits. They should then be examined for the other traits listed and rejected if they fail to meet the minimum standards. Selected trees should be marked with distinctive tags, ribbons, or paint spots. Except for fruitfulness, these traits apply to male trees of dioecious species as well as the seed-bearing trees. Thus it is essential to mark the best male trees to leave in the stand. All disqualified trees should then be removed.

TABLE 5.—Qualification standards for seed trees on seed-production areas

STEP NO. 1.--SPECIFY MINIMUM STANDARD FOR NOT MORE THAN THREE TRAITS CONSIDERED MOST IMPORTANT

Trait	Minimum specifications (See section on individual tree traits for help in drawing these up)
1. ______	______
2. ______	______
3. ______	______

STEP NO. 2.--DISQUALIFY ALL TREES THAT DO NOT MEET THE FOLLOWING STANDARD FOR OTHER TRAITS

Trait	Standard	Minimum specification acceptable[1] For veneer	For poles and saw logs	For Pulpwood
Stem form				
Straightness	Inches of crook or sweep in first log	4	4	4
Taper	Lower, equal, or higher than average form factor of species in stand	Equal	Equal	Equal
Roundness	Ratio small d.b.h. over large d.b.h.	0.96	0.85	0.85
Lean	Degrees from vertical	2	4	2
Apical dominance	Percentage of total height with single main stem			
	Hardwoods	75	75	75
	Conifers	85	85	85
Branching habit	Number branches below 17 feet	4	4	8
	Degrees from vertical	Less than 45	Less than 45	Less than 45
	Forking below 17 feet	None	None	None
Vigor	Total height greater, equal, or less than average height of neighboring trees (same species)	Equal	Equal	Equal
Surface defects	Number below 17 feet	6	6	8
Pest resistance	Degree of resistance	Moderate	Moderate	Moderate
Grain	Degrees spiral grain	5	10	10
Seed crops	Good, medium, or poor	Poor	Poor	Poor

1/ Cross out specifications for traits already listed in step No. 1.

Most traits need no further description. In some cases "vigor" may have to be determined by increment borings and crown classification. For example, an intermediate white ash in a mixed or uneven-aged stand may be potentially acceptable as a seed tree. Density and size of crown also indicate vigor and present or potential fruitfulness.

Spacing the Seed Trees

It is generally known that open-grown trees produce more seed than those growing in dense stands (*49*). Studies in both hardwood and coniferous stands have shown that thinning nearly always increases seed production. Most publications on pine seed-production areas indicate optimum spacing for maximum seed production in number of trees or in basal area per acre. Moreover, pine seed is almost invariably collected from pure stands. For hardwood species, especially the oaks, we will often find our best seed trees in mixed stands. In mixed stands, hardwood or conifer, it is therefore not practical to set up spacing guides for marking the "leave" trees. Each prospective tree should be considered by itself, and all other trees removed that might interfere with its growth and crown development. There must, however, be at least two or three other trees of satisfactory quality within pollinating distance of each selected seed tree.

The selected seed trees — whether conifer or hardwood, in pure or mixed stands — should be given plenty of room for crown development. As a general rule, the space should be wide enough so that the entire length of the live crown is in direct sunlight for at least half the day during the growing season (fig. 18). This applies to the selected male trees or dioecious species as well as to the seed trees. Remaining trees of other species need not be removed from the stand unless they interfere with maintenance of the area or with seed collection. If windthrow is a factor, consider thinning twice, 2 or 3 years apart. Trees removed should be felled (not girdled) and hauled out of the area. Or they may be placed in windrows where they will not interfere with seed collection.

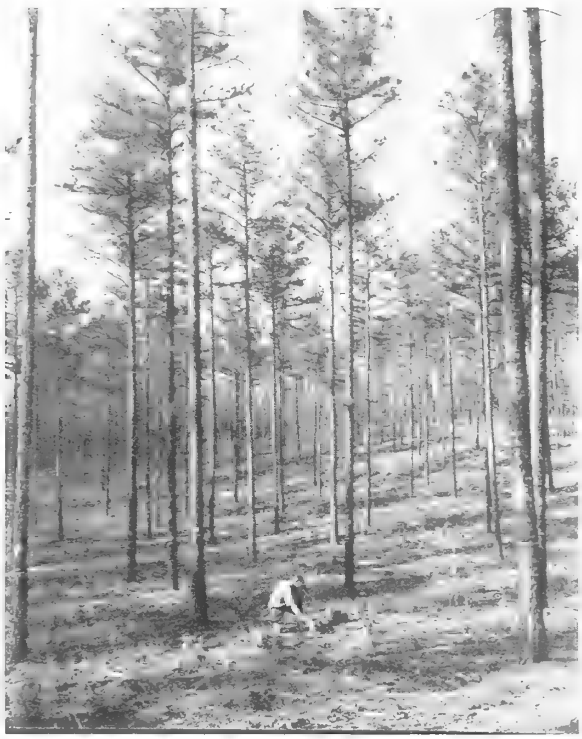


FIGURE 18.—Shortleaf pine seed-production area, Clark National Forest, Missouri. Note wide spacing of trees and room for good crown development.

Roguing

In the first cut remove all trees of the species selected for seed production that do not meet minimum specifications and are not needed for the protection of the stand from windthrow. Substandard trees left in the first cut should be similarly "rogued" as soon as they are not needed for further protection of the selected seed trees. For dioecious species, female trees not selected as seed trees may be retained in the stand if they do not interfere with the full crown development of adjacent seed trees, and if they are needed for protection of the stand. These rules apply, of course, only to species selected as seed trees in the stand.

Understory Treatments

Remove all brush and understory trees that would interfere with the maintenance of the area and with seed collection. As a minimum, this would include all brush and understory trees 20 to 30 feet beyond the outer limits of the seed-tree crown.

Isolation Zones

Isolation zones 400 feet wide around the seed-production area are recommended. No seed should be collected from trees in the isolation zone. Rogue all trees of the seed-tree species that have disqualifying traits. No other treatment of the isolation zone seems necessary. For dioecious species, only disqualified male trees need be rogued.

Fertilizers

Not much information on the use of fertilizers is yet available. After seed-production areas have been established, soil tests can be arranged through the local county agricultural agent to determine nutrient deficiencies. Exploratory fertilizer applications based on these soil tests and advice of research agencies can be initiated on parts of the seed-production area.

Until precise fertilizer prescriptions for each seed-production area have been determined, Faulkner and Matthews (*33*) recommend 100 pounds of phosphorus and 100 pounds of potassium per acre per year as a good start. Nitrogen and potassium should be applied in early spring before shoot growth begins. Late fall may be the best time to apply phosphorous fertilizer. Where seed trees make up the bulk of the stand, fertilizer may be broadcast over the entire area. Where individual seed trees are scattered, which may be common in hardwood seed-production areas, only the area within 1½ times the radius of the crown should be fertilized.

Disease and Insect Problems

In thinning and slash disposal, residual trees must be protected from disease and insects. Beware, especially, of the *Fomes annosus* fungus after felling trees in pine seed-production areas. Keep informed of research now underway on the prevalence and control of cone and acorn insects. If disease or insect damage is likely, all stumps should be treated and slash disposed according to the best known sanitation measure.

Plantations as Seed-Production Areas

Most of the conifer seed-production areas in the region will have to be established in plantations; in some localities natural stands of shortleaf pine, redcedar,and white pine may be available. Plantations may also be desirable as seed-production areas for some hardwood species such as sweetgum. It is desirable to know seed origin. But even more important in using plantations as seed-production areas are adaptation of the trees to the site and locality and whether growth and quality to a merchantable size are superior (or at least satisfactory). For species not native to a state or locality, and used extensively for planting, the establishment of seed-production areas in local plantations may be necessary. It would, in fact, be far safer to use seed from local plan-

tations satisfactory in growth and quality than from questionable sources of distant origin. There is, however, one drawback in using local plantations of unknown origin as seed-production areas. If trees in the plantation happen to be of the same parentage or only one stand, the progenies may be the result of inbreeding. If so, they may not be of the same quality as their parents.

The principles regarding spacing, tree selection, site treatment, isolation zones, and so forth, are the same for establishing seed-production areas in plantations as for natural stands.

Seed Orchards

The establishment of seed orchards as the principal source of seed for future planting is desirable. In the Central States, species commanding highest priority for seed orchards are yellow-poplar, black walnut, eastern cottonwood, white pine, loblolly pine, and shortleaf pine. Techniques for setting up seed orchards differ with species. Little is yet known about optimum spacing, cultural practices, and propagation for some species. Seed orchards should be initiated only in cooperation with research agencies.

Only a few promising progeny-tested seed trees are now available. But enough research has been done to aid in the selection of potentially outstanding trees. To speed up the availability of improved seed it appears desirable to conduct progeny studies and establish seed orchards for some of our important species at the same time. Trees can be removed from seed orchards as soon as poor performance of their progeny indicates poor genotypes (*89*). The quality of seed orchards will then be improved as soon as results of progeny studies become available. The following guides may help in deciding the number and kinds of seed orchards to establish.

Classification (*69*)

Seed orchards are of three general types: Seedling seed orchards are made up of seedlings produced from selected parents through natural or controlled pollination. Clonal seed orchards are made up of selected clones propagated by grafting, budding, or rooting of cuttings. Seedling-clonal seed orchards result from top-grafting branches onto trees in seedling orchards. Parentage of stock used in both seedling or clonal seed orchards usually has been or is being progeny-tested.

Whether seedling or clonal seed orchards should be established is still controversial (*47, 74, 135, 168*). But we are certain that the

choice will depend a great deal on the species. Black walnut seedling seed orchards, modified later by top-grafting of additional selected material, for example, appear practicable. Seed may be produced on a commercial scale in 10 years. As nuts are collected from the ground, height of seed trees will present no problem. For yellow-poplar, on the other hand, good yields of seed from seedling orchards may not be expected in less than 15 years. In that time the trees may be so tall that collecting seed will be costly. For this species, clonal orchards seem most desirable, especially if seed can be produced at low heights.

Number of Sources to Use

Some apprehension prevails over the few sources often used in seed orchards. Problems in pollination, compatibility, seed quality, and inbreeding diminish as more selections are used. To minimize these problems Wright and Bull (*170*) advocate the use of more than 100 selections in conifer seedling orchards. Trees would be closely spaced so that as many as 90 to 99 percent can eventually be rogued out, leaving a residual spacing not greater than 20 by 20 feet. This minimum is also desirable for hardwoods. This means that before seed orchards are established for any species, a concentrated, systematic search for many superior trees is imperative.

Site Selection

Seed orchards should be located on well-drained, fertile soils. The site should be accessible to motor vehicles and level enough to permit the use of machinery for cultivation and seed harvesting. Late spring frosts may damage seed orchards as much as fruit orchards. Therefore, upper slopes and ridgetops should be favored and "frost pockets" should definitely be avoided. Control of isolation strips should be assured, at least for 400 feet, so that undesirable trees of the species for which the seed orchard is established can be removed from this zone.

Site Preparation and Maintenance

If the site is located on forested land, all trees and brush should be removed and treated to prevent regeneration. On all sites, planting strips at least 8 feet wide should be scarified by plowing or disking. Spacing of strips will depend on spacing of trees to be planted; for black walnut, and perhaps many other species, the strips may be 18 feet apart center to center. Cultivation may be necessary for at least 2 or 3 years after planting; mulching and fertilizing may also be desirable (fig. 19). Where rabbits are numerous, trees should be protected by screens. After establishment has been assured, a grass or legume ground cover should be developed; this will require periodic mowing during the growing season.

Getting Started on a Seed Improvement Program

Development of a good forest tree seed improvement program in the Central States is important (*94*) in improving forest planting practices. Some of the essential steps toward developing such a program are:

1. Make a survey to determine, in order of importance, the species to be planted in the future; consider current and long-range needs. Conifers will most likely be in large demand for a few years until most of the old fields and brush areas are planted. But after these become planted, hardwoods will become increasingly more important. Some coniferous planting will still be needed, however, on oak-pine sites and on low-grade hardwood sites where conversion plantings are desired.

2. Set up seed-source specifications for each species, listing in order of preference the geographic sources and tree characteristics desired. It is futile to set up the highest quality standard for all traits (*142*). Specify the highest standard for one or two (never more

than three) of the most important characteristics desired. Then set lower specifications for other traits.

3. Alert all field personnel to search for and report promising trees and stands (*157*), planted or natural, on private or public land that may be suitable for supervised seed-collection and seed-production areas (*127, 139*).

4. Maintain a record of seed sources available by purchase from other agencies, states, and regions for all species to be used in your planting program.

5. Select seed sources to be used in order of preference. Ordinarily, supervised collection from local sources is best. But seed of high quality and suitable for the locality from other agencies, states, and regions should not be overlooked.

6. When purchasing seed, favor certified seed; avoid use of "questionable seed" as much as possible.

7. With advice from research agencies, establish seed-production areas (*125*) for the more important species used in present and future planting programs (*30, 45*).

8. With advice and cooperation of research agencies, begin the establishment of seed orchards. Begin with species that will be important from a long-range view and continue with other species to be used extensively in future planting programs.

9. Work out "reciprocal seed treaties" with other agencies to avoid unnecessary duplication of effort in establishing seed-production areas and seed orchards for the same seed-collection zones.

FIGURE 19.—Preparing site for a black walnut seedling seed orchard. Eight-foot strips, 18 feet apart, plowed, disked, fertilized, and treated for grub control. (Courtesy Ohio Division of Forestry.)

Recommendations by Species

The following seed-procurement recommendations are presented to help administrators of planting programs obtain the highest quality seed available for present planting projects and to aid them in planning for better seed in future planting projects. The material is presented mainly to aid in deciding whether to purchase seed of a particular species, to get it by supervised collections, to set up seed-production areas, or to establish seed orchards. Under "special seed-tree specifications," only those of special significance for the species are given. In general, the standards for individual tree traits should also be considered; to avoid repetition they are not listed in detail for each species.

Alder, European (Black)

(*Altnus glutinosa* (L.) Gaertn.)

Flowering and seeding habits. — Monoecious; wind pollinated, usually protogynous and largely self-compatible (*86*). Flowers of both sexes develop from catkins partially formed the previous autumn. Precocious, some trees bearing seed when only 3 years old with heavy production at 5 years. Seed crops regular but quality variable, with germination ranging from less than 1 to more than 80 percent. Seed is ripe as soon as it turns brown; best seed apparently falls first (*145*). In the Central States, seed should probably be collected in early October most years.

Genetic variation. — Differences in height growth are apparently clinal and correlated with latitude. Seedling height growth is correlated with seed weight and bud size of parent trees (*159*).

Seed-source preferences. — The Spreewald area in Germany, about 80 kilometers southeast of Berlin, is considered the best alder seed source by most Europeans. Other good provenances from early Central States trials are an area south of Munich in Upper Bavaria and extreme southeast Denmark, along the coast. Thrifty but slow-growing strains suitable for nurse trees, are available from south-central Sweden.

Special seed-tree specifications. — Emphasize straight, single-stemmed trees with flat branch angle, good foliage color, and no evidence of insect attack.

Seed purchases. — Quality of most commercial seed is acceptable but be sure to insist on a germination test. Seed imported from Germany is classified by collection zones; Zone II — 12 is probably best (and highest priced).

Seed-collection and seed-production areas. — Not justified on any large scale since seed orchards can be easily and quickly put into production.

Seed orchards. — Seedling seed orchards are probably best for such a precocious tree although alders grow rapidly from cuttings (*86*).

Ash, Green

(*Fraxinus pennsylvanica* Marsh.)

Flowering and seeding habits. — Dioecious; cross-pollinated by wind, good seed crops nearly every year. Green ash bears seed early in life, sometimes only 5 to 6 years after planting. But good seed crops may not come until a few years later when trees are 3 to 4 inches d.b.h. and 20 feet tall. Flowers are borne over the entire crown (*166*). They appear in the spring before leaf buds start to enlarge. Pollen, dispersed by wind, travels only short distances; most of it falls within 200 to 300 feet.

Genetic variation. — Studies (*166*) indicate existence of geographic ecotypes differing in resistance to drought and low winter temperature. Meuli and Shirley (*91*) reported that progenies from the northwestern part of the plains region were more drought resistant than those from the more moist central part of the region. In Massachusetts Wright found that progenies from northern New England seed sources grew more slowly but were much more frost-hardy than those from South Carolina sources. Trees from the southern sources grew vigorously during summer but died back nearly to the ground each winter. Attempts to cross green ash with velvet ash (*F. velutina* Torr.) have been successful. Crosses with white ash (*F. americana* L.) and European ash (*F. excelsior* L.) yielded no identifiable hybrids.

Seed-source preferences. — Throughout the region it is desirable to collect green ash seed from the subzone in which the planting is planned. Seed from sources east of the 80- to 100-day precipitation-distribution sector in Missouri and Iowa should not be used in this sector.

Special seed-tree specifications. — Straightness, form, surface defects, etc., need to be considered (figs. 20, 21, 22, and 23). Vigorous, fast-growing trees possess the toughness and other desirable properties of ash required in most of the products for which it is used. Bark characteristics provide a good indication of ash vigor and quality. Vigorous trees have bark with low ridges and shallow depressions between them, so that the bark appears to be tight; between the ridges light-colored streaks of inner bark are readily seen all seasons of the year (*109*).

Seed-collection areas. — Good seed may be collected from trees felled in commercial logging. If possible, cutting should be scheduled at the time seed of high-quality trees is ripe, or shortly afterward. When this is not possible and no seed is available from seed-production areas or seed orchards, collect seed from trees and stands of the highest quality available.

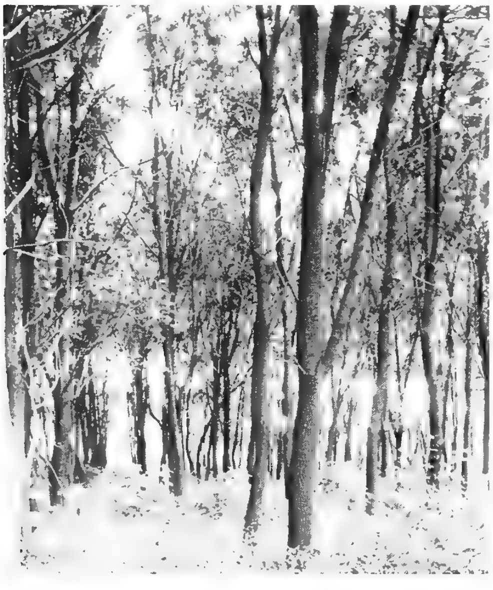
Seed-production areas. — Because green ash is dioecious it is necessary to retain both trees bearing male flowers and those bearing female flowers in the stand. Pollen apparently does not travel far and trees with different flowers should be located within 300 feet of each other. This can be done by identifying and marking male and female trees before selections are made. Only the male trees of undesirable quality need to be rogued. It may be best to establish green ash seed-production areas in young stands just approaching the seed-production age. This would facilitate collections and perhaps make it easier to shape crowns for greater seed production. Tree quality, however, should take precedence over age in selecting production areas. General rules for selecting seed trees, spacing, treatments, and maintenance in seed-production areas may be followed.

Seed orchards. — Green ash bears seed at an early age so establishment of seedling seed orchards seems practicable. But because it can be propagated by budding, eventual development of a "seedling clonal" orchard appears promising. Budding can be used to top-work scion material from specially selected superior trees onto branches of the stock plant. In this way it is possible to improve pollination and quality of progeny.

FIGURE 20.—Planted green ash trees with heavy limbs and acute branch angle. Both traits are unsatisfactory and may be inherited.

FIGURE 21.—Green ash with small branches and almost horizontal branch angle. This plantation is better in both traits than that shown in figure 20.

FIGURE 22.—Green ash plantation of extremely poor quality, 21 years old, on good site in Indiana. Poor quality is most likely due to poor seed source selection.



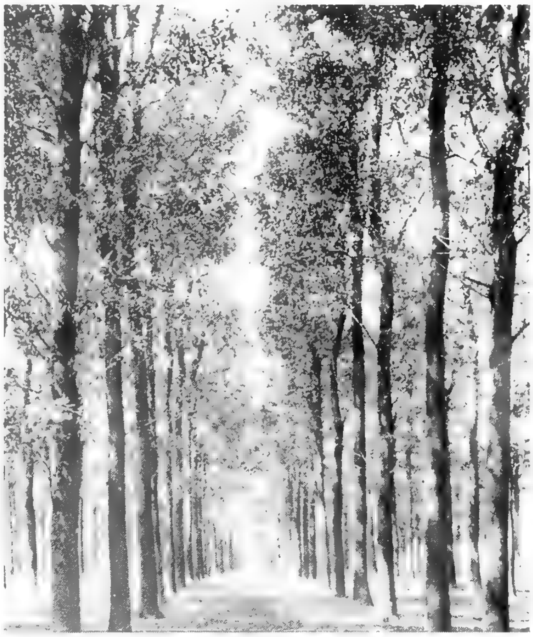


FIGURE 23.—Green ash plantation of exceptionally good quality near and similar to site shown in figure 22.

Ash, White

(*F. americana* L.)

Flowering and seeding habits. — Similar to green ash, except that trees may not produce seed on a large scale before they are 20 years old and good seed crops can be expected less frequently — every 3 to 5 years.

Genetic variation. — According to Wright (*167*) there are three presently recognized geographic ecotypes of white ash. A northern ecotype found in Canada, northern New England, New York, and the Lake States is winter-hardy, slow-growing, subject to early leaf-fall, and susceptible to aphid attacks. An intermediate ecotype found in western Connecticut, southern Pennsylvania, northern West Virginia, and parts of Ohio is more like the northern than the southern ecotype. A southern ecotype found from Maryland west to southern Indiana and southward is more variable than the others. It is faster growing, less susceptible to aphid attack, and less winter-hardy. There are apparently no hybrids of white ash and other ash species.

Seed-source preferences. — Limit collection to the seed-collection zone in which planting is planned. It would be better to collect seed in the same zone even if this were in an adjacent state than from north or south of the zone. It would, of course, also be very desirable if collections were made in the same subzone in which the planting area is located.

Special seed-tree specifications. — Same as for green ash.

Seed-production areas. — Same as for green ash.

Seed orchards. — Same as for green ash.

Cottonwood, Eastern

(*Populus deltoides* Bartr.)

Flowering and seeding habits (*36*). — Dioecious (*35*); cross-pollinated by wind, good seed crops every year. Flowering occurs in early spring, usually before leaves have formed, and seeds usually mature a month to 6 weeks later. In most stands the number of male and female trees is about equal; there are, no doubt, exceptions to this ratio. Seed bearing on a commercial scale begins at about age 8 to 10.

Genetic variation. — Because of the wide range and flowering habits of cottonwood, progenies of different parentage differ tremendously. So much variation occurs that if uniform stock is desired the planting of cuttings from a single clone may be necessary. One of the important sources of variation should be recognized in planting cottonwood is its sensitivity to differences in latitude between seed source and planting site (*105*). Jokela[2] reports 4-year-old cottonwood from a source in southern Illinois was 1.4 times as tall as a local source in plantings in east-central Illinois. Stock planted north of its origin may grow rapidly but may not be winter-hardy enough. The time in the fall that growth in height ceases depends on latitude of origin of seed or clone. That is, trees from southern sources continue to grow later in the fall than trees from northern sources. For progeny from sources in the same latitude but different altitudes, cessation of growth depends on the

[2]Personal correspondence with Mr. Jalmer J. Jokela, Department of Forestry, University of Illinois, May 2, 1963.

length of the frost-free growing season. Breaking of dormancy in the spring, however, is controlled mainly by existing temperatures rather than photoperiod. Differences in susceptibility to insects and disease are also probable. Jokela found 3 to 5 percent of the native cottonwoods in central Illinois to be highly resistant to the *melampsora* rust. "Siouxland cottonwood" is certified by the state of South Dakota as resistant to leaf rust and leaf spot.[3] The cottonwood root and stem borer (*Paranthrene dolli* Neum.) may be a serious insect pest for some cottonwood selections; there is some evidence that sources differ in susceptibility. Cottonwood hybridizes readily with many other species of *Populus*. Several natural hybrids occur and thousands of hybrids have been developed by man. But only a few are of commercial importance.

Seed- or clonal-source preferences. — Latitude and length of growing season of the area of planting are probably the most important factors to consider in choosing geographic sources of seed or clones. As a general rule, stay within the same seed-collection zone. Sources in adjoining states — in the same zone — are satisfactory. Selections from the adjacent subzones to the north or south may be satisfactory. But those from farther north may grow at a reduced rate and those from farther south may lack winter-hardiness. Several outstanding cottonwoods and hybrids have been selected and are being evaluated in many localities; check with local research agencies about their availability before choosing other sources of stock (*134*).

Special seed-tree specifications. — Look especially for trees that appear to resist borers and other insects and such diseases as canker. Samples of wood, for the assessment of wood quality by a research agency, would be desirable (*9*).

Seed-collection areas. — Select seed (or clonal material) from trees and stands of the best quality available. Avoid collecting seed from a single tree or stand! It is better to mix seed from several trees and stands of each seed-collection zone than to use seed from a single tree or stand. If possible, avoid stands with many poor-quality trees even though no seed is collected from the poor trees.

Seed-production areas. — As with green and white ash, both male and female cottonwood trees must be retained in the stand for good seed production. One of the first jobs to do is to identify and mark the male and female trees in the stand; this should be done in the spring at the time of flowering. Rogue out all low-quality male cottonwoods within 500 feet of selected seed trees, and if feasible, within ½ mile of the seed-production area.

Seed orchards.[4] — Cottonwood seedling seed orchards are recommended because trees may bear seed at an early age. Seed bearing on a commercial scale may be possible in 6 to 8 years on good soil that is fertilized and cultivated. Space cuttings about 40 by 40 feet, with one male to five or six females. The cuttings should be made from 40 to 60 different selections. These selections should be of the best quality possible and widely scattered over the entire seed-collection zone in a state. Special selections from inside or outside the zone that have been recommended by research agencies can also be included. Progeny studies, at standard spacing, should be established at about the same time. Unsatisfactory clones may be removed from the seed orchard and replaced by new selections as their progeny become old enough to be evaluated. It is better to collect seed from all or most trees in a seed orchard rather than from just a few trees. This is true even when only a small quantity may be needed (*44*).

Cutting nurseries.[4] — To supply the current demand for cottonwood planting, and to supply large quantities of selected material for seed orchards, the establishment of cutting

[3]Personal correspondence with Mr. John C. Barber, formerly Project Leader, Southeastern Forest Experiment Station; now Project Leader, Institute of Forest Genetics, Southern Forest Experiment Station, April 25, 1963.

[4]Boyce, Stephen G. Improve eastern cottonwood through recurrent selection. (Manuscript in preparation for publication.)

plots is recommended. Cuttings from the most outstanding selections available should be planted 3 feet apart in rows 6 feet apart. At the end of the first season cuttings can begin to be made. Cut the tree at the ground line; this will result in the production of the most usable cuttings the following year. As plantations established from seed-orchard seed develop, the best progenies can be used in the cutting plots and to replace selections rogued out of the seed orchard. By continuing this cycle (recurrent selection) the quality of cottonwood plantations can be constantly improved.

Larch, European
(*Larix decidua* Mill.)

Flowering and seeding habits. — Monecious; male and female flowers mature in early spring just before the new leaves (*23*). Trees attain commercial seed-bearing age in 10 to 15 years; heavy crops probably occur no more frequently than every 5 years (*148*).

Genetic variation.—Taxonomically, the species is segregated into two varieties: *L. decidua* Mill. var. *decidua* is known as the Alpine variety; *L. decidua* var. *polonica* (Racib.), Ostenf. and Larson, known as the Carpathian variety, includes the Sudeten, Slovakian, and Polish provenances. McComb (*83*) has reported on these four provenances or geographical races of European larch. The Alpen (Alpine) race of the central Alps occurs at higher elevations of 2500 meters down to about 300 meters. The Sudeten race is found in the part of Czechoslovakia with the same name, generally between 300 and 850 meters. It is reported to be faster growing than the Alpen. The Tatra (Slovakian) race is found in the mountains of Czechoslovakia and Poland between 700 and 800 meters and the Polen (Polish) race occurs between 150 and 600 meters from Silesia through central and southeast Poland. It has now been fairly well established that trees from these different geographic sources differ in growth rates, form, and resistance to disease when planted outside their natural range (*42*). Dunkeld larch (X *Larix eurolepis* A. Henry), a hybrid of European larch and Japanese larch, is a promising tree that generally grows faster than either parent and is more resistant to aphids and fungi than the European larch parent. Crosses of European larch with the following larches have also been reported: *L. gmelini* (Dahurian larch), *L. laricina* (Du Roi) K. Koch (tamarack), *L. occidentalis* Nutt. (western larch), *L. sibrica* Ledeb. (Siberian larch), and *L. mastersiana* Rheder and Wilson (Master's larch).

Seed-source preferences.—Seed should preferably be obtained from trees of acceptable quality in local plantations. If none is available from these sources, seed from the Polen provenance is next in preference, then the lower elevations of the Alpen and Sudeten provenances (*31*).

Seed purchases. — Certified seed, showing altitude of source, would be preferable; avoid purchase of seed from altitudes above 500 meters.

Seed-collection areas. — Collect seed only from plantations having a high percentage of trees of acceptable quality. Especially avoid stands that include many slow-growing, poorly formed trees and many trees seriously injured by disease or insects.

Seed-production areas. — Desirable if suitable plantations can be located and needs will warrant the expense of establishment and maintenance. General directions for pine seed-production areas would be applicable.

Seed orchards. — Both clonal and seedling seed orchards are feasible (*95*). But reports on larch orchards in Europe (*75*) indicate commercial seed production may be realized from seedling seed orchards nearly as soon as from clonal orchards. Seedling seed orchards may, therefore, be more practicable because they cost less to establish.

Larch, Japanese

(*L. leptolepis* (Sieb. and Zucc.) Murray)

Flowering and seeding habits. —Same as for European larch.

Genetic variation. — In a provenance study in Europe, Langner (*73*) reports differences between several sources in growth rate but none that depended on altitude of parent stock. The "Woody-Plant Seed Manual" (*148*) mentions that three different forms or races are recognized in Japanese larch planted in England. Its most important hybrid is with European larch to form Dunkeld larch (described under European larch). Japanese larch is reported to be more resistant to pests than European larch, but less resistant to drought, injury from early and late frosts, and breakage from ice and snow (*42*).

Seed-source preferences. — From local plantations of acceptable quality. Sources certifying suitable growth rate and form would be next best.

Seed-collection areas. — Same as for European larch.

Seed-production areas. — Same as for European larch.

Seed orchards. — Same as for European larch.

Locust, Black

(*Robinia pseudoacacia* L.)

Flowering and seeding habits. — Perfect flowers; insect pollinated and appearing in May and June in the Central States. Seed ripens in September and October. Heavy seed crops occur nearly every year. Trees may begin seed production on a commercial scale in 6 to 8 years.

Genetic variation. — Reports of genetic differences in black locust are somewhat conflicting and experimental evidence is rather scanty. But there seems little doubt that individual trees differ in growth rate and stem form and that this is at least partially controlled by heredity. Current research with this species is concentrated on finding or developing trees that are resistant to the locust borer (*Megacyllene robiniae* Forst.). Black locust is sensitive to late spring frosts, but some trees are more resistant to this type of injury than others.

Seed-source preferences. — Black locust has been widely planted and naturalized over the Temperate Zone. Sources of native origin would be difficult to identify. The safest sources would be local stands or trees of merchantable size and of the quality desired.

Special seed-tree specifications. — In order, the most important traits to consider are resistance to the locust borer, tree form, and growth rate.

Seed-collection areas. — Make collections from stands or trees of merchantable size and of the quality desired.

Seed-production areas. — Should be established only if a stand of trees of exceptional quality can be found.

Seed orchards. — Because black locust produces seed at an early age seedling seed orchards appear practical. But seed orchards of this species do not seem warranted until borer-resistant trees have been found or developed (consult research agencies).

Maple, Silver
(*Acer saccharinum* L.)

Flowering and seeding habits. — Polygamo-dioecious. Insect pollinated (with some self-pollination), flowers appearing in early spring (*84*). In the Central States seed matures generally during April and May, depending on geographic location and weather. In natural stands seed bearing begins generally in 25 to 30 years and abundant crops occur almost every year. But good seed crops have been observed on individual trees 5 to 7 years old growing in the open.

Genetic variation. — Differences are extensive, even locally (*84*). Trees appear to differ greatly in sensitivity to low temperature. This may account for most of the multiple-stemmed specimens seen in many silver maple plantations. Other regional and local differences in growth rate, wood quality, and susceptibility to disease may exist although no experimental evidence is available. Interracial crosses may possess hybrid vigor or other desirable traits. Hybridization with red maple has been reported.

Seed-source preferences. — Silver maple's known sensitivity to low temperature makes it extremely important to collect seed within seed-collection subzones for each state or from sources north of the proposed planting sites.

Special seed-tree specifications. — Look especially for seed trees that are single-stemmed.

Seed-collection areas. — Avoid collecting seed from trees planted in cities and parks unless origin of trees is known and acceptable.

Seed-production areas. — If large-scale planting of silver maple is planned, the establishment of seed-production areas is recommended. Because of the dioecious flowering habit, it is important that both male and female trees should be selected and retained in the stand. Follow the guides for cottonwood.

Seed orchards. — According to reports by McKnight and Bonner (*84*), silver maple propagation by grafting and budding is easy. Establishment of clonal orchards by either method therefore seem practical.

Cutting nurseries. — Cuttings of silver maple are also easy to root (*84*). To meet the current demand for planting stock, cutting nurseries as outlined for cottonwood may be useful.

Maple, Sugar
(*A. saccharum* Marsh.)

Flowering and seeding habits.—Polygamous (both perfect and unisexual flowers occur on the same tree); usually bee pollinated. Flowers appear in the spring about the time leaves appear; seeds mature in the fall. Commercial seed-bearing age is generally 25 to 35 years and good crops occur about every second to fifth year.

Genetic variation.—Much geographical variation in sugar maple has been reported (*72*). Leaf shape differs sufficiently for some taxonomists to recognize several subspecies. Geographical variation in drought susceptibility, leaf scorch, frost resistance, and winter hardiness has been established. And, of special importance in this species, is the existence of definite inherited differences in sap content and quality. Kriebel (*72*) has recognized three types that are not entirely distinct from each other but have common regional characteristics. The northern hardwood ecotype includes individuals of both the *saccharum* and *nigrum* subspecies and intermediates. Trees are

characterized by low genetic resistance to drought and high resistance to winter injury. Because dormancy breaks early in the spring, the trees are susceptible to slight injury from late spring frosts. The central ecotype is characterized by high resistance to drought and winter injury and again includes individuals of both the *saccharum* and *nigrum* subspecies. Kriebel's southern ecotye is identical with the subspecies *floridanum*. It is characterized by high resistance to drought, only moderate resistance to winter injury, and poor form because of a tendency toward repeated forking of main and lateral shoots. Trees from several sources were compared in survival and growth 8 years after planting in a trial in Tennessee (*174*). Those from sources in Illinois and Tennessee were best, those from New Jersey and Vermont were poorest in survival, and those from New Hampshire, Michigan, and New Jersey poorest in growth. Hybrids among the subspecies and with red maple (*A. rubrum* L.) have been reported (*48*).

Seed-source preferences. — Selection of geographic sources is important because of apparent differences in drought and winter hardiness. For these reasons selections should be made within the seed-collection zone in which the planting is planned. Transfers from the adjacent subzone to the south are permissible to take advantage of seed from trees of exceptional quality. It may be questionable in dry areas (less than 100 days of 0.01 inch of precipitation per year) to use seed from moist areas (more than 100 days of 0.01 inch of precipitation per year).

Special seed-tree specifications. — These depend on the objective of planting; for timber production the usual properties of straightness, absence of lean, high vigor, etc., are most important. If syrup or sugar production is an objective, seek trees with exceptional sugar yield or quality.

Seed-collection areas. — No special precautions necessary; follow general directions.

Seed-production areas. — No special precaution necessary.

Seed orchards. — Clonal seed orchards appear to be more practicable than seedling seed orchards for this species. If seedling seed orchards are established, commercial seed production may not be attained until 30 years after planting. The clonal seed orchard can be established by both budding and grafting. Seed production may be realized in 5 to 10 years.

Oaks

(*Quercus* spp.)

Flowering and seeding habits. — Monoecious; wind pollinated. There is some selfing, but the percentage of self-pollinated flowers is believed to be small. For oaks planted in the Central States (white, northern red, bur (*Q. macrocarpa* Michx.), chestnut (*Q. prinus* L.), the minimum seed-bearing age is not less than 25 years. Good seed crops rarely occur in white oak oftener than every 5 to 10 years (*18*); good seed crops occur about every 2 or 3 years in other oak species (*144*).

Genetic variation. — Widely distributed oak species can be expected to exhibit great geographic variation in growth habits and in susceptibility to drought and low temperature (*150*). Provenance studies have recently been established for northern red oak and will soon furnish information on the kind and extent of differences. There is much natural hybridization in oaks; many local differences in vigor, straightness, branching habits, forking, etc. have been reported (*58*). Hybridization of oaks

in Russia on a comprehensive scale has been reported by Piatnisky (*108*).

Seed-source preferences. — Until the results of current studies are evaluated, it is advisable to make separate seed collections for each zone and state.

Seed-production areas. — Seed-production areas will no doubt be the best source of seed for oak species far into the future. Their establishment for species to be planted extensively is strongly recommended. Stands with many good-quality trees should be located. For oaks it may be especially desirable for adjacent states to make reciprocal seed treaties, so that both can benefit from the best seed sources. A stand located in an adjacent state may be more suitable for some areas in the state — if in the same seed-collection zone — than stands located in a different zone in the same state.

Seed orchards. — The opportunities for successful oak seed orchards appear discouraging. Commercial seed bearing from seedling seed orchards does not seem possible in less than 20 years. It is still very difficult to root cuttings from old trees, but success in grafting has been reported (*58*). Until these techniques are well developed, clonal seed orchards will not be practicable.

Pine, Austrian

(*Pinus nigra* Arnold) (*P. austriaca* Hoess) (*P. laricio* Poir.)

Flowering and seeding habits. — Monoecious. Flowers appear in spring, cones opening in the fall of the following growing season. The minimum commercial seed-bearing age is about 30 years. Good seed crops can be expected about every 3 or 4 years.

Genetic variation. — Many varieties and subspecies of Austrian (Corsican) pine occur in southern Europe. Because it is found naturally in several habitats differing greatly in climate, trees from different sources can be expected to differ in susceptibility to drought and low temperature.

Seed-source preferences. — Seed from local plantations of acceptable quality should be used until more suitable sources have been found. Current provenance trials, recently established by the North Central Association of Agricultural Experiment Stations, may soon provide more definite information on suitability of seed sources (*171*).

Seed purchases. — Unless a proven source is available, obtain seed from areas with climate and latitude similar to those where planting is planned.

Seed-production areas. — If local plantations of acceptable quality are available, they may be developed as seed-production areas. Consider first, however, the demand and need for seed of this species in future planting programs.

Seed orchards. — Clonal and seedling seed orchards are feasible, but they should not be started until results are obtained from recently established provenance trials.

Pine, Eastern White

(*P. strobus* L.)

Flowering and seeding habits. — Monoecious. Minimum commercial seed-bearing age in the Central States is 15 to 20 years; good seed crops occur every 3 to 5 years.

Genetic variation. — Early results from a provenance study recently established indicate, as expected, wide geographic variation in growth rate (*138*). In general, trees from more northern sources such as Canada and the northern United States do not grow as fast as trees of local origin. In contrast, trees from more southern sources grow faster than trees of local origin. Individual trees and stands that are inherently superior in many desirable traits can no doubt be found (*40*). Some success in locating strains resistant to blister rust has been reported and there is hope that weevil-resistant strains can also be found (*172*). Several hybrids with other species of five-needled pines have been reported (*172*).

Seed-source preferences. — Until specific sources have been proven superior, seed from local natural stands or plantations of acceptable quality should be given priority. If seed is available from neither, the following sources are suggested:

For planting in Iowa and northern Illinois, obtain seed from central Wisconsin, southern Michigan, and Tennessee.

For planting in northern Indiana and northwestern Ohio, obtain seed from southern Michigan, central Wisconsin, and Tennessee.

For planting in Missouri, southern Illinois, and Kentucky, obtain seed from Tennessee, Kentucky, and North Carolina.

For planting in southern Indiana and southern and eastern Ohio, obtain seed from Tennessee, Ohio, Kentucky, West Virginia, and North Carolina.

Special seed-tree specifications. — Look especially for trees above average in self-pruning, branch size, vigor, and freedom from defects that might be due to past weevil or blister rust attacks.

Seed-collection areas.—Local natural stands and plantations of acceptable quality are suitable as collection areas until seed-production areas and orchards are available.

Seed-production areas. — Until seed from orchards becomes available, seed-production areas would be the best source of supply.

Seed orchards. — Clonal orchards will be the best source of seed for white pine planting in the region. But they should not be started until a number of superior trees of desired provenance have been located for grafting.

Pine, Jack
(*P. banksiana* Lamb.)

Flowering and seeding habits. — Monoecious. Jack pine may begin bearing seed on a large scale as early as 5 years after planting. Fair crops annually; good crops every 3 to 5 years.

Genetic variation. — As with most widely distributed species, geographic variation has been found. Differences in growth rate and form are the most important (*121, 132, 160*). Individuals within a stand have also been observed to differ greatly in form and branchiness. Geographic and stand differences in resistance to pests have been noted (*1*). Natural hybrids with lodgepole pine (*P. contorta* Dougl.) have been observed in Canada (*124*).

Seed-source preferences. — Local plantations with many trees of acceptable quality are preferred. If not available, sources in lower Michigan, central Wisconsin, and the southern part of the jack pine range in Minnesota should be used (*158*).

Seed purchases. — From certified seed from suitable geographic sources and known quality.

Seed-collection areas. — From local stands of acceptable quality.

Seed-production areas. — From local stands of acceptable quality.

Seed orchards. — Large-scale planting of jack pine in the Central States appears improbable. Sometimes seed may be obtained from local plantations or certified seed of suitable geographical origin purchased. If either is available, the establishment of jack pine seed orchards in the Central States does not seem warranted at this time.

Pine, Loblolly
(*P. taeda* L.)

Flowering and seeding habits. — Monoecious. Commercial seed bearing cannot be expected before trees are 12 to 15 years old (*158*). Cross-pollinated by wind; effective pollination distance less than 300 feet. Good seed crops occur erratically every 3 to 10 years.

Genetic variation. — No distinct races of loblolly pine have been discovered. But great differences in growth rates, hardiness, resistance to disease and insects, and in form among geographic sources and from stand to stand have been reported (*143, 154, 158*). In experimental plantings in southern Illinois, trees from sources in Virginia, Maryland, and Arkansas grew taller and survived better than those from sources in Mississippi, North Carolina, and South Carolina (*92, 162*). In another experimental planting in southern Illinois reported by Zarger (*176*), trees from inland sources in Alabama, Mississippi, and Tennessee survived and grew better than those from three Atlantic coast sources in Maryland and Virginia. Loblolly pine has been crossed with several other pines, notably pitch (*P. rigida* Mill.), shortleaf, and slash pine (*P. elliottii* Engelm.). Sonderegger pine (*P.* X *sondereggeri* H. H. Chapm.) is a natural hybrid of loblolly and longleaf (*P. palustris* Mill.) pines.

Special seed-tree specifications.—In plantations look especially for straight trees with no spiral grain and few branches in the lower 17 feet of the stem.

Seed-production areas. — Should be located in local plantations of acceptable quality. Techniques for establishing loblolly pine seed-production areas have been perfected in the South (*19*, *29*, *87*).

Seed-source preferences. — Local plantations and seed orchards of acceptable quality are the preferred seed sources. Where no local source is available, a Maryland, Virginia, or Arkansas source is next best.

Seed orchards.— If seed is obtainable from local plantations, seedling seed orchards may be the most practical kind to establish. If most of the seed must be obtained outside of the state, clonal seed orchards should be started. Many superior trees from acceptable geographic locations should be used in establishing either type of orchard. Seed from clonal seed orchards can probably be harvested on a commercial scale in 10 to 15 years and from seedling orchards in 15 to 20 years.[5]

[5]Personal communication with Mr. John C. Barber, formerly Project Leader, Southeastern Forest Experiment Station; now Project Leader, Institute of Forest Genetics, Southern Forest Experiment Station, April 25, 1963.

Pine, Red

(*P. resinosa* Ait.)

Flowering and seeding habits. — Monoecious. The minimum commercial seed-bearing age is 25 to 30 years. Good seed crops occur every 3 to 7 years (*123*).

Genetic variation. — A review of literature reveals local differences in red pine as well as geographical variation (*4*, *15*, *32*, *56*, *57*, *116*, *117*, *118*, *119*, *123*). In northeastern Minnesota trees from local sources in 18 years produced more than 2½ times the cubic volume of trees from the most distant source used. In general, trees from sources in the warmer parts of red pine's natural range are less frost-resistant and tend to start shoot growth earlier in the spring than those from sources in the colder parts. But in at least one study (*14*) trees from 48 different sources did not significantly differ in height growth on eight different geographic areas 24 years after planting. These results underscore the need for considering local as well as regional differences in selecting red pine seed sources. Only one hybrid of red pine with other species is known. This is a cross with Austrian pine that was developed at the Western Institute of Forest Genetics. But so far it does not apear to have any practical significance.

Seed-source preferences. — Local plantations of acceptable quality or certified seed from southern Michigan, Minnesota, and Wisconsin.

Seed purchases. — State agencies in Michigan, Minnesota, and Wisconsin and reputable seed dealers appear to be safe sources of seed.

Seed-production areas. — If local plantations have trees of acceptable quality and much seed is needed for future programs, the establishment of seed-production areas would be desirable.

Seed orchards. — The establishment of seed orchards for this species should not be given high priority. This is both because good seed can be obtained from local seed-production areas or from reputable agencies in Michigan, Minnesota, and Wisconsin and because seed orchards would make for little genetic gain in seed quality.

Pine, Scotch

(*P. sylvestris* L.)

Flowering and seeding habits. — Monoecious. Good seed crops may be expected 5 to 10 years after planting and thereafter every 2 to 3 years. Detailed records of flowering and seeding of this species have been published by Sarvas (*131*).

Genetic variation. — The extreme differences in growth rate, form, and foliage color in this species are well known (*136*). Gerhold (*43*) reports that foliage color, an important property in the Christmas tree trade, differs according to latitude and altitude of parental stock. In general, fall yellowing of needles is common in trees from Latvia, Scandinavia, Finland, and the Urals. Differences in growth rate among trees from 10 sources planted in southern Michigan (*128*) were noticeable; trees from seed originating in Finland, Rumania, and Norway were shorter than those from seed originating in Poland, the Netherlands, Lithuania, and White Russia.

Seed-source preferences. — Unless a foreign source of proven quality is available, the best sources of seed are from plantations of acceptable quality in the Central States or the Lake States. Many dealers offer Scotch pine seed for sale; seed certified as to quality and geographical origin should be preferred.

Special seed-tree specifications. — For timber production look especially for growth rate, form, and branch characteristics; for Christmas trees, fall foliage color and growth rate are the most important traits to consider.

Seed-production areas. — A good source of seed if local plantations of acceptable quality are available.

Seed orchards. — Both clonal and seedling seed orchards are feasible. Clonal seed orchards may yield seed in commercial quantities a few years earlier than seedling seed orchards, perhaps in 5 years, but may be much more difficult and costly to establish. Seedling seed orchards might yield seed in commercial quanties in 8 to 10 years (*170*). Clonal seed orchards of Scotch pine are common in Europe (*75*).

Pine, Shortleaf

(*P. echinata* Mill.)

Flowering and seeding habits. — Monoecious. Good seed crops occur erratically and not in the same year throughout the range of the species (*54, 153, pp. 30-32*). Commercial seed crops cannot be expected before trees attain 15 to 20 years.

Genetic variation. — In the southwide pine seed-source study (*154*), significant differences in survival and growth of shortleaf pine have been observed. In Missouri, trees from northern sources survived better than those from southern sources. But differences in height 7 years after planting were insignificant (*115*). Inherent differences in straightness, form, and branching habit of shortleaf pine have been reported by Dorman (*27*), Campbell (*16*), and others.

Seed-source preferences. — In Missouri and Kentucky natural stands within subzones should be preferred. Seed from outside the subzone, particularly from outside the State, should not be used unless the source is known to be satisfactory. For Illinois, obtain seed from local plantations within the State or from

natural stands in Missouri. For Indiana and Ohio, select seed from plantations of acceptable quality from natural stands of acceptable quality in Ohio, or from subzone 6b in Kentucky and West Virginia.

Special seed-tree specifications. — Look especially for straight trees with better-than-average taper, good natural pruning, superior height in the stand, and good branching habit (*175*). See suggested form for "Selecting Superiod Tree Candidates," page 59 in the Appendix.

Seed purchases. — Do not purchase seed unless the geographical origin is known and suitable for the area to be planted.

Seed-collection areas.—Stands that include many trees of good quality are satisfactory. Collection in connection with logging operations from trees felled at the time of seed maturity or shortly thereafter is also satisfactory, especially if trees of highest quality are selected.

Seed-production areas. — Shortleaf pine seed-production areas are highly desirable. They may serve as interim sources of good seed until seed orchards are established or as long-term sources if future planting will be too small to justify the establishment of seed orchards. A few guides for establishing shortleaf pine seed-production areas have been provided by Brinkman (*12*) and by Phares and Rogers (*107*).

Seed orchards. — Seedling seed orchards appear to be very practical if a good source of seed such as a seed-production area composed of many high-quality trees is available and the species is promient in future planting plans. Clonal orchards may be worth establishing if a good local source of seed is not readily available. Neither should be started, however, until enough superior trees suitable for the subzone (a minimum of 15) are available as sources of scion material. Grafting and pollination techniques, necessary for the establishment of southern pine seed orchards, have been fairly well standardized (*19*, *46*, *62*, *106*, *173*, *178*).

Redcedar, Eastern

(*Juniperus virginiana* L.)

Flowering and seeding habits. — Dioecious, rarely monoecious; unisexual flowers usually borne on separate trees. Commercial seed bearing usually does not begin before trees are 10 to 15 years old. Good seed crops occur about every second or third year.

Genetic variation. — There is much inherent variation in eastern redcedar and many different forms are propagated for ornamental purposes (*2*). Minckler and Ryker (*93*) have reported geographical variation in color of foliage, form of stem and crown, growth, and resistance to rust. There is also some evidence of interspecific hybridization in *Juniperus* (*161*).

Seed-source preferences. — Experimental plantings made in southern Illinois included eight different geographic sources. The most suitable progeny in survival, growth, and color of foliage 6 years after planting was that from a Wilson County source in north-central Tennessee (*93*). More information on seed-source differences is needed from plantations in other parts of the region. Until such information becomes available, do not collect out of state. Instead collect separately for each seed-collection zone and state.

Special seed-tree specifications.—Look especially for trees that grow rapidly and seem to resist cedar-apple rust. If Christmas trees are

the main objective, color of fall foliage is important.

Seed-collection areas. — Natural stands and plantations containing many trees of acceptable quality should be used.

Seed-production areas. — Would be highly desirable if volume needed justifies their establishment and management. Wide spacing would permit full crown development and greater seed production. Trees bearing male flowers should be retained in the stand to assure good pollination.

Seed orchards. — Recommended in states where large-scale planting of redcedar is planned, but only when seed from many superior trees is available. Seedling seed orchards seem more practicable than clonal orchards.

Spruce, Norway

(*Picea abies* (L.) Karst.) (*P. excelsa* Link)

Flowering and seeding habits. — Monoecious. Commercial seed production may not begin before trees are 30 to 50 years old. Good seed crops may not occur more frequently than every 4 or 5 years.

Genetic variation. — In Europe many geographic races have been discovered, as well as marked differences within a stand. A great many varieties are recognized (*23*). Differences in growth rate and form, regardless of geographical origin, are the most important selection factors for the Central States (*129*).

Seed-source preferences. — First choice should be from plantations of acceptable quality in the Central States or the northeastern states. No seed from abroad should be used unless quality as well as geographic source is certified (fig. 24).

Seed-production areas. — Desirable, if local plantations with trees of acceptable quality are available.

Seed orchards. — Clonal seed orchards appear the most practical. But these should not be attempted unless the anticipated needs justify their establishment and until enough trees of acceptable quality are available for use in grafting.

FIGURE 24. — High-quality Norway spruce plantation in Iowa. For exotic species seed from good local plantations is better than foreign seed of unknown source and quality.

Sweetgum

(*Liquidambar styraciflua* L.)

Flowering and seeding habits. — Monoecious; wind pollinated, and most likely self-incompatible. Commercial seed crops begin when the trees are about 20 years old (*88*); fair crops are borne every year and bumper crops every 2 or 3 years.

Genetic variation.—No information is available on geographic variation or races. But sweetgum is known to be very susceptible to frost. Trees from sources on the northern edge of the natural range are probably more winter-hardy than those from sources located farther south.

Seed-source preferences.—Obtain seed from natural stands or plantations located in the subzone where trees are to be planted. If not available from the same subzone, get seed from the adjacent subzone north or south.

Seed purchases.—Geographic sources should be specified.

Seed-collection areas. — To insure that seed will be high in viability and to get more cross-pollination, it is better to collect from stands containing many sweetgum trees than from stands containing only a few. Seed collected from selected trees following logging is also satisfactory. High-quality trees are, of course, needed.

Seed-production areas. — Seed-production areas in plantations or stands of acceptable quality are desirable and highly recommended (fig. 25).

Seed orchards. — No specific information yet available; clonal seed orchards would be desirable.

FIGURE 25.—Good sweetgum plantation in central Ohio. Plantations like this would be satisfactory for seed-production areas and may provide good scion material for seed orchards.

Sycamore, American
(*Platanus occidentalis* L.)

Flowering and seeding habits. — Monoecious; cross-pollinated by wind. Dichogamous and therefore rarely if ever self-pollinated. The minimum commercial seed-bearing age is reported to be 25 years; good seed crops are borne nearly every year, apparently depending chiefly on absence of late spring frosts.

Genetic variation. — No definite information is available on genetic variation in sycamore (*90*). The species is known to be susceptible to injury by late spring frosts and it is often injured by the anthracnose disease. Geographical strains probably differ in winter hardiness and in resistance to anthracnose. *P. occidentalis* hybridizes with *P. orientalis* L. to form *P.* X *acerifolia* (Ait.) Willd., the London plane-tree commonly planted as a shade tree in the United States.

Seed-source preferences. — Because of the possibility of differences in winter hardiness, it is advisable to collect seed no farther south than the subzone where trees are to be planted.

Seed-collection areas. — Collect seed from trees in stands containing many sycamores rather than from single, isolated trees. Even though a single tree may provide enough seed to meet current needs, it is better to collect seed from several trees and mix it.

Seed-production areas. — Select areas with stands containing many sycamores, preferably young stands just approaching seed-bearing age. Remove all trees shading or crowding seed trees to permit full crown development. Cut back tops of a few of prospective seed trees to see if this increases seed production.

Seed orchards. — Appear unnecessary for this species. One well-selected tree may produce an enormous quantity of seed. If a number of high-quality trees can be found in the same vicinity and the area developed as a seed-production area, the quality as well as quantity of seed produced would most likely be satisfactory. For long-term needs, however, it may be desirable to conduct a progeny study and establish a seedling seed orchard of seedlings from superior trees widely scattered within the subzone.

Walnut, Black
(*Juglans nigra* L.)

Flowering and seeding habits. — Monoecious; cross-pollinated by wind, and dichogamous. Commercial crops of seed may be produced when trees are 10 to 12 years old; good crops occur about every 3 or 4 years.

Genetic variation. — Evidence of local and geographic variation has been reported by Wright (*165*). In field trials in northern Indiana he recognized three possible geographic races: (1) Northwest from Iowa, Minnesota, Wisconsin, and Michigan; (2) Central from Illinois, Indiana, Maryland, Missouri, Ohio, Pennsylvania, West Virginia, and the mountainous part of Virginia; and (3) South from Alabama, Georgia, North Carolina, South Carolina, Tennessee, and the central part of Virginia. Local differences in height growth, leaf persistence in the fall, dieback incidence, and anthracnose resistance have been noted. Individual trees no doubt differ greatly in inherited form, straightness, and number of

branches; it is known that inherent differences also exist in the incidence of pin-knots, grain, and other wood properties (*156*). The horticulturists recognize many varieties differing in nut quality and nut production. Black walnut has been hybridized with several *Juglans* species, but not with butternut (*J. cinerea* L.). The two species are apparently incompatible.

Seed-source preferences. — Until more precise information is obtained on effects of different geographical origin on survival and growth, it is advisable to obtain seed from the zone in which the trees are to be planted. The quality of the seed tree itself (*67*, *68*) appears to be far more important than geographic location.

Seed-collection areas. — Avoid making collections from isolated seed trees. It is better to collect from a tree within 300 feet of a few other walnut trees of good quality than from one farther away. Also avoid collecting from a seed tree in a stand containing many other walnut trees of poor quality.

Seed-production areas. — Highly desirable, particularly if it is possible to rogue out all inferior trees and still have enough to insure good cross-pollination.

Seed orchards. — Highly desirable and both clonal and seedling seed orchards are practicable. Because walnut trees may start bearing seed as soon as 10 years after being planted, seedling seed orchards appear promising (*112*). When additional seed trees of the desired quality are available, these can be added to the orchard by top-grafting their scion wood onto the crown of trees already present, or by interplanting seeds or seedlings (*137*). Dichogamy must be considered in establishing black walnut seed orchards. Because selections may differ in dates of flowering and pollination, it is important that many of them (a minimum of 15) be used on each acre of seed orchard. When flowering begins studies can be made to learn what trees are compatible (*52*). Progeny trials that can be undertaken concurrently on suitable planting sites should reveal what seed trees are suitable (*20*). Then those selections that are neither compatible nor of acceptable quality can be removed from the orchard. If trees are spaced 18 by 18 feet, about 144 trees per acre can be planted in the orchard. When trees are mature a minimum space of 54 by 54 feet per tree or a "residual" stand of about 16 trees per acre is desirable. It is thus possible to rogue out many selections to assure seed production from only the most desirable seed sources.

Yellow-Poplar

(*Liriodendron tulipifera* L.)

Flowering and seeding habits. — Flowers perfect; pollination by insects. Although there is some selfing, most pollen is incompatible with the styles of the same tree (*10*). The result is that self-pollination is largely ineffective. For the same reason, some cross-pollination is also ineffective. Incompatibility is, therefore, the major cause of low viability of yellow-poplar seeds. The minimum age of seed bearing on a commercial scale is 15 to 20 years. Good seed crops occur every 2 or 3 years, but good crops do not occur the same year in all stands or localities (*53*).

Genetic variation. — From current seed-source studies (*78, 79, 81, 140, 150*) there is mounting evidence of much inherent variation within and among trees from geographical sources of yellow-poplar. Funk (*41*) has reported trees from various geographic sources differ markedly in frost resistance. Differences in height growth and form between individual seed trees in a stand and between stands are becoming evident.

Seed-source preferences. — Seed for planting in each seed-collection subzone should come from trees in that subzone. Avoid seed from trees located far to the south of the planting sites. The selection of individual seed trees (*82*) and stands is also highly important (*113*).

Seed purchases.—Geographic source should be known; if geographic source is satisfactory and planting stock carefully graded, plantations of fairly good quality can be established.

Seed-collection areas. — Select stands with many trees of acceptable quality. Seed collected from trees felled in logging high-quality stands is also satisfactory, especially when resulting seedlings are carefully graded at the nursery.

Seed-production areas. — Select young stands of high quality just approaching seed-bearing age; thin to provide plenty of room for good crown development. Cut back tops of a few seed trees to see if this boosts seed production.

Seed orchards.—Clonal seed orchards would be highly desirable. Because of the incompatibility problem, it will be necessary to use many different selections. If possible, two or more selections should be budded on the same stock. Beehives in the orchard may also boost cross-pollination.

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Appendix

Easy Ways for Measuring Some Traits of Tree Quality

Quantitative measures of tree quality are highly desirable in tree improvement work. In establishing seed-production areas, measurable criteria for comparing and selecting prospective seed trees are very useful. And in evaluating prospective superior tree candidates as sources of material for seed orchards and breeding, records based on measurements are far more meaningful than those based on descriptive terms alone.

An easy way to measure crown surface area has been developed (*22*).

Such important traits as lean, branch angle, spiral grain, and roundness can be measured with reasonable accuracy with two common forester's tools, a tree caliper and a transparent semicircular protractor. Attach a string with a weight to the "center" of the protractor (fig. 26). To facilitate sighting, especially in dark, shaded woods, a narrow strip of masking tape should be placed along one edge of "the line" from the "center" to the 90-degree point.

To measure lean.— Standing 50 or more feet away from the tree, line up the protractor

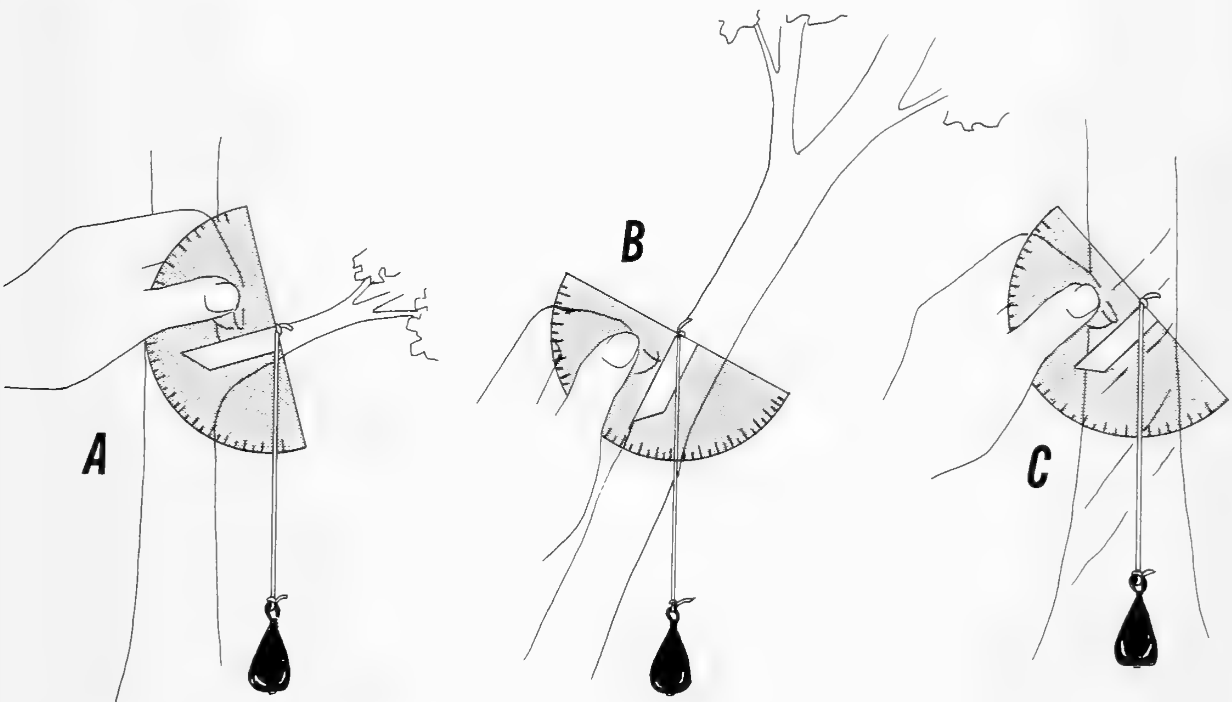

FIGURE 26.— Easy way to measure some traits of tree quality: (a) branch angle, (b) lean, and (c) spiral grain.

so that the base line is parallel to the edge of the tree to be measured and allow the plumb line to fall freely. The reading at the plumb line indicates the lean in degrees from vertical (fig. 26).

To measure branch angle.—Measure branch angle in the same manner as lean of stem. Set the protractor parallel with branch slope, allow plumb line to fall freely, and take reading in degrees from vertical (fig. 26). Upright branch angles could be "plus" readings; downward angles "minus" readings. If the stem of the tree at branch fork is not approximately vertical, take a "lean" reading. Then add (or subtract) it from the branch angle reading to give you a more precise branch angle measurement.

To measure spiral grain. — Spiral grain can be measured by determining the "lean" of the general course of bark ridges or furrows on the tree (fig. 26). For example, for high-quality wood a spiral grain of more than 7 degrees would generally be unacceptable.

To measure roundness. — With tree calipers determine the largest and smallest d.b.h. The ratio of small d.b.h. over large d.b.h., or "roundness ratio," is a good measure of this characteristic. A ratio of 0.95 or better is generally regarded as good for most products, 0.85 to 0.95 "acceptable," and less than 0.85 as "unacceptable."

Selecting Superior Tree Candidates

Rating System for Shortleaf Pine Sawtimber in the Central States

Favor selection in natural even-aged stands 40 to 60 years old; restrict use of a form to a single stand and site. Reject all trees with one or more of the following traits: (1) spiral grain or twist; (2) excessive lean (more than 2 degrees from vertical); (3) forking; (4) intermediate or suppressed crown class; (5) evidence of susceptibility to serious pests or storm damage — (*Cronartium*, little leaf, top breakage, etc.); (6) branch angle in upper half of crown less than 45 degrees; (7) roundness — ratio less than 0.85; (8) less than 90 percent apical dominance.

Comparative Ratings of Candidates in Stand

Trait	Rating	Tree number						
STEM FORM								
Straightness:								
1. Straight (no visible crook or sweep)	A							
2. Acceptable: (less than 2-inch crook or sweep from 4.5 to 17 feet)	B							
3. Poor (more than 2-inch crook or sweep)	C							
Taper:								
1. Better than average in stand	A							
2. Average	B							
3. Poorer than average	C							
BRANCHING HABIT								
Number of branches or stubs below 17 feet (self-pruning):								
1. None	A							
2. 1 to 5	B							
3. More than 5	C							
Branch angle:								
1. 75 to 90 degrees	A							
2. 45 to 75 degrees	B							
3. Less than 45 degrees	C							
Branch diameter:								
1. Smaller than average in stand	A							
2. Average	B							
3. Larger than average	C							
HEIGHT SUPERIORITY								
1. 15% higher than average dominant in stand	A							
2. 10 to 14% higher	B							
3. Less than 10% higher	C							
SEED CROPS								
1. Heavy	A							
2. Average	B							
3. Poor	C							
SURFACE DEFECTS (Number of bumps, bulges, etc.)								
1. None	A							
2. 1 to 5	B							
3. More than 5	C							
RATING TOTALS								
Numerical rating (All ratings ± 1 point) A = 6 B = 3 C = 0								
Age of tree, years -								

INSTRUCTIONS:

Numerical ratings should be placed in one block for each trait. Basic value of 6-3-0 for A-B-C can be adjusted ± 1 point if desirable to give a ± value for a given trait.

Tree No._________ is a superior tree candidate.

Rating System for Loblolly Pine Plantations

(Pulpwood)

Favor selection in stands over 20 years old; restrict use of a form to a single stand and site. Reject all trees with one or more of the following traits: (1) spiral grain or twist; (2) excessive lean (more than 2 degrees from vertical); (3) forking; (4) evidence of susceptibility to serious pests or storm damage—*Cronartium*, top breakage, etc.; (5) crown class—intermediate or suppressed; (6) roundness—ratio less than 0.85; (7) less than 90 percent apical dominance.

Comparative Ratings of Candidates in Stand

Trait	Rating	Tree number						
STEM FORM								
Straightness:								
1. Straight (no visible crook or sweep)	A							
2. Acceptable: (less than 2-inch crook or sweep from 4.5 to 17 feet)	B							
3. Poor (more than 2-inch crook or sweep)	C							
Taper:								
1. Better than average in stand	A							
2. Average	B							
3. Poorer than average	C							
BRANCHING HABIT								
Number of branches or stubs below 17 feet (self-pruning):								
1. Less than 6	A							
2. 6 to 10	B							
3. More than 10	C							
Branch angle:								
1. 75 to 90 degrees	A							
2. 45 to 75 degrees	B							
3. Less than 45 degrees	C							
Branch diameter:								
1. Smaller than average in stand	A							
2. Average	B							
3. Larger than average	C							
HEIGHT SUPERIORITY								
1. 15% higher than average dominant in stand	A							
2. 10 to 14% higher	B							
3. Less than 10% higher	C							
SEED CROPS								
1. Heavy	A							
2. Average	B							
3. Poor	C							
SURFACE DEFECTS (Number of bumps, bulges, etc.)								
1. None	A							
2. 1 to 5	B							
3. More than 5	C							
RATING TOTALS								
Numerical rating (All ratings ± 1 point) A = 6 B = 3 C = 0								
Age of tree, years -								

INSTRUCTIONS:

Numerical ratings should be placed in one block for each trait. Basic value of 6-3-0 for A-B-C can be adjusted ± 1 point if desirable to give a ± value for a given trait.

Tree No.________ is a superior tree candidate.

Favor but do not restrict selection in pure even-aged stands of seed-bearing age; restrict use of one form to a single species, stand, and site. Reject all trees with one or more of the following traits: (1) spiral grain or twist; (2) excessive lean (more than 3 degrees from vertical) (4 degrees for oaks); (3) forking; (4) crown class—intermediate or suppressed; (5) evidence of susceptibility to serious pests or storm damage—cankers, conks, top breakage, etc.; (6) roundness—ratio less than 0.85.

Species________________

Comparative Ratings of Candidates in Stand

Trait	Rating	Tree number						
STEM FORM Straightness: 1. Straight (no visible crook or sweep)	A							
2. Acceptable: (less than 2-inch crook or sweep from 4.5 to 17 feet)	B							
3. Poor (more than 2-inch crook or sweep)	C							
Taper: 1. Better than average in stand	A							
2. Average	B							
3. Poorer than average	C							
BRANCHING HABIT Number of branches or stubs below 17 feet (self-pruning): 1. None	A							
2. 1 to 5	B							
3. More than 5	C							
Branch angle: 1. 75 to 90 degrees	A							
2. 45 to 75 degrees	B							
3. Less than 45 degrees	C							
Branch diameter: 1. Smaller than average in stand	A							
2. Average	B							
3. Larger than average	C							
HEIGHT SUPERIORITY 1. 15% higher than average dominant in stand	A							
2. 10 to 14% higher	B							
3. Less than 10% higher	C							
SEED CROPS 1. Heavy	A							
2. Average	B							
3. Poor	C							
SURFACE DEFECTS (Number of bumps, bulges, etc.) 1. 4 or less	A							
2. 5 to 8	B							
3. More than 8	C							
RATING TOTALS								
Numerical rating (All ratings $\pm$ 1 point) A = 6 B = 3 C = 0								
Age of tree, years -								

INSTRUCTIONS:

Numerical ratings should be placed in one block for each trait. Basic value of 6-3-0 for A-B-C can be adjusted $\pm$ 1 point if desirable to give a $\pm$ value for a given trait.

Tree No.__________ is a superior tree candidate.

Directions for Reporting Promising Trees and Stands

In order to carry out a good tree improvement program a large reservoir of individual trees must be made available for study. Your cooperation is needed in reporting the location of any trees that may qualify as superior or that have special or unusual characteristics. On the next page you will find a sample form outlining the kind of information needed. You may send this report, in duplicate, to your organization headquarters. Or send a single copy directly to the Central States Forest Experiment Station, 111 Old Federal Building, Columbus, Ohio 43215. A central file of all reports will be maintained in the Station headquarters. Copies of reports on individual trees or species will be furnished anyone upon request. The Station also has a supply of convenient report cards for this purpose to simplify these reports; they also are available upon request.

Trees reported in this manner will be examined by qualified foresters and classified for future use. Wood samples may be taken, and a complete evaluation will be recorded on the form that follows.

REPORT ON PROMISING OR UNUSUAL STAND OR TREE

Species____________________________

Total Ht.___ft; DBH___inches; Age____years

Stand (species)______________________

Average Ht.___ft; DBH___inches; Age____yrs

Planted ( )   Natural ( )

State____________ County______________

Nearest Town________________________

Forty__________ Sec.____ T.____ R._____

Name of farm or tract_________________

Owner's name and address_______________

____

Reasons for reporting; outstanding or unusual qualities in:

( ) Straightness

( ) Growth rate

( ) Health & vigor

( ) Crown development

( ) Self pruning

( ) Branch development

( ) Stem form (taper)

( ) Seed production

( ) Grain

( ) Wood quality

RESISTANCE TO:

( ) Weather injury

( ) Insects

( ) Diseases

( ) Animals

Other__________________________________

SKETCH OR MAP

(Scale: side of each square is _____ long)

Reported by: Name________________________

Address________________________

Date____________________

(See other side for evaluation of report)

CENTRAL STATES FOREST TREE IMPROVEMENT COMMITTEE

EVALUATION OF REPORT OF PROMISING OR UNUSUAL TREE

Tree No.___ Species______________________ DBH______ Tot.Ht._________ Age_________

Location and ownership data--change copy of original report and map on other side as needed. Elevation above sea level_______ Latitude_______ Longitude___________

Crown class_________ Shape__________ Length________ Width_______ Density__________

Clear length______ft. Double bark thickness at b.h.________ 17' diameter_________

Roundness: Large DBH_____(L); Small DBH_____(S); S/L_______ Class_______________

Fluting: None ( ) Shallow ( ) Deep ( ). Grain________ Lean_________degrees.

Sweep and crook: Edge of stem does not depart from line of sight with a straightness more than _________ inches on any side from stump to 17'. Class______________

Branch size shorter_____ or longer______, smaller______ or larger_______ than average sizes of branches in adjacent trees.

Branch angle in upper half of crown____________degrees.

Insect or disease defects: Kinds______________________ Significance_____________

Fruitfulness: Heavy ( ), Moderate ( ), or Poor ( ) seed crop estimated: male tree ( ), with good ( ) or poor ( ) flowering likely.

Wood quality: percent sapwood_____; specific gravity__________; average fiber length __________; percent summerwood__________; color of sapwood______________ color of heartwood____________; grain___________________.

Other tree or wood characteristics of outstanding or unusual quality______________

____

____

Classification: This tree is suitable for seed collection ( ), as part of a seed production area ( ), as source of seed or propagules for use in seed orchards ( ), for breeding ( ). Can tree be classed as superior?____________________________

____

Evaluated by______________________________________
Name and position

Date_______________________

____
Address

(See other side for copy of original report)